VOLUME XI JULY, 1928 NUMBER 4

JOURNAL OF DAIRY SCIENCE

OFFICIAL ORGAN OF THE
AMERICAN DAIRY SCIENCE ASSOCIATION

Contents

Physical Constants of the Milk as Influencing the Centrifugal Separation of Cream at Various Temperatures. PAUL FRANCIS SHARP 259

Growth in Weight of Guernsey Cows After the Age of Two Years. CHARLES W. TURNER 265

Lipins and Sterols as Sources of Error in the Estimation of Fat in Buttermilk by Ether Extraction Methods. L. M. THURSTON AND W. E. PETERSEN 270

A Comparison of Certain Methods for Determining the Sanitary Quality of Ice Cream. JOHN WEINZIRL AND L. S. HARRIS. 284

The Effect of Flash Pasteurization of Milk upon the Flavor and Texture of Cheddar Cheese. C. A. PHILLIPS 292

Effect of Homogenizing Ice Cream Mixes Before and After the Addition of Gelatin or Sugar and Before and After Condensing. J. C. HENING 299

The Effect of Hydrogen Ion Concentration on the Bacterial Content of Gelatin. A. C. FAY 313

A Comparison of the Volatile-Solvent Method with the Vacuum-Oven Method for Determining Moisture Content of Cheese. GEORGE P. SANDERS 325

Book Reviews 331

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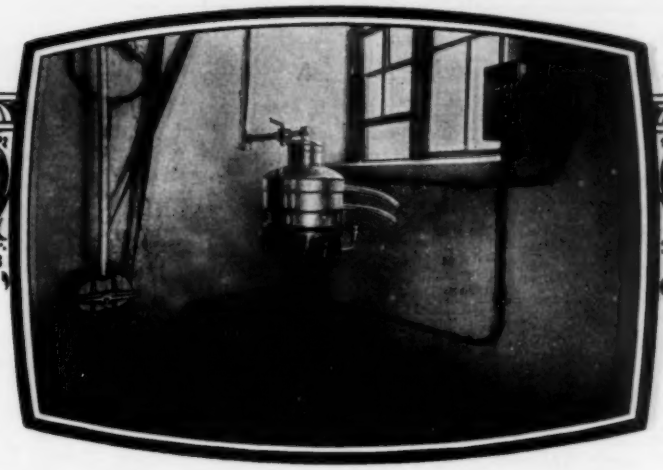

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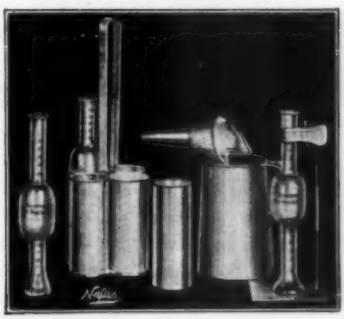

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PHYSICAL CONSTANTS OF THE MILK AS INFLUENCING THE CENTRIFUGAL SEPARATION OF CREAM AT VARIOUS TEMPERATURES*

PAUL FRANCIS SHARP

Chemical Laboratory of the Department of Dairy Industry, Cornell University, Ithaca

Studies by Rahn (4) van der Burg (1), (2) van Dam and Sirks (3) and Troy and Sharp (5) have shown that Stokes equation indicates quite accurately the rate of rise of individual fat globules through milk plasma under the influence of gravity. Troy and Sharp (5) have also shown that the rate of rise of clusters of fat globules through milk plasma is in agreement with this equation. Stokes equation is as follows:

$$V = \frac{2\, r^2\, (d_p - d_f)\, a}{9\, \eta} \qquad (1)$$

Where V is the rate of movement of the fat globule in centimeters per second, r the radius of the fat globule, η the viscosity of the milk plasma, d_p and d_f the density of the plasma and fat respectively, and a is the acceleration. In the case of fat globules rising under the influence of gravity, a is the gravational constant and is numerically equal to 980 dynes.

This equation can also be used to calculate the velocity of the movement of fat globules through the plasma due to the centrifugal force of the cream separator, by expressing a in terms of the acceleration produced by the centrifuge. Equation (2) gives the value of a, when the acceleration is due to centrifugal force.

$$a = \frac{(2\, \pi\, n)^2\, R}{(60)^2} \qquad (2)$$

Where n is the number of revolutions of the separator bowl per minute, and R is the distance of the fat globule from the axis of rotation. Thus the rate of movement of a fat globule through

* Received for publication February 1, 1928.

the milk plasma due to the centrifugal force at any instant, is given by the following equation:

$$V = \frac{2\, r^2\, (d_p - d_f)\, 4\, \pi^2\, n^2\, R}{9\, \eta\, 3600} \tag{3}$$

Since several of the factors in the equation are numbers they may be gathered together into a numerical constant which has the value 0.00244. The equation then becomes:

$$V = \frac{0.00244\, (d_p - d_f)\, r^2\, n^2\, R}{\eta} \tag{4}$$

Equation (4) is of general applicability. In order to apply the equation to the separation of fat from milk, all of the factors in equation (4) which are independent of the dimensions and speed of the separator and the size of the fat globules were gathered into a constant K, which varies with the temperature.

$$K = \frac{0.00244\, (d_p - d_f)}{\eta} \tag{5}$$

The velocity of movement then is given by the equation:

$$V = K\, r^2\, R\, n^2 \tag{6}$$

For a given cream separator, if the speed of the bowl and rate of flow of the milk through the separator are held constant, then the rate of movement of the fat globules through the plasma, and consequently the effective force tending to separate the fat, depends on the value of K, which in turn is controlled by the densities of the plasma and fat and by the viscosity of the plasma. A glance at the equations shows that the separation would be more complete the greater the difference in density between the fat and the plasma, and the lower the viscosity.

Since temperature markedly affects the density of the fat and the viscosity of the plasma, the values for K were calculated for 5°C. intervals of temperature from 5° to 80°C. to show how the effective force tending to separate the cream in a given separator increases with temperature. The results are given in table 1.

The data in columns (2) and (5) are taken from the paper by Whitaker, Sherman and Sharp (6). The density of the fat, column (3), was determined experimentally with pycnometers. The value of K for the various temperatures is given in column (6).

The density and viscosity both change in such a way as to make the separation more efficient at the higher temperatures.

TABLE 1

Density of plasma and fat, and the viscosity of the plasma as affecting the velocity of movement of the fat globules under centrifugal force

TEMPERATURE	DENSITY OF PLASMA d_s	DENSITY OF FAT d_f	DIFFERENCE $d_s - d_f$	VISCOSITY	K	K^1	PERCENTAGE INCREASE IN K^1 FOR EACH 5°C. INTERVAL INCREASE IN TEMPERATURE
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
°C.				poise			per cent
5	1.0365	0.9612	0.0753	0.0296	0.0062	0.0062	
10	1.0359	0.9528	0.0831	0.0247	0.0082	0.0083	33.0
15	1.0348	0.9421	0.0927	0.0210	0.0108	0.0110	33.0
20	1.0338	0.9304	0.1034	0.0179	0.0141	0.0144	30.9
25	1.0322	0.9208	0.1114	0.0154	0.0176	0.0181	25.9
30	1.0306	0.9119	0.1187	0.0133	0.0218	0.0226	24.9
35	1.0288	0.9082	0.1206	0.0117	0.0252	0.0262	15.9
40	1.0266	0.9050	0.1216	0.0104	0.0285	0.0297	13.4
45	1.0245	0.9012	0.1233	0.0093	0.0323	0.0337	11.3
50	1.0223	0.8982	0.1241	0.0085	0.0356	0.0372	10.4
55	1.0198	0.8945	0.1253	0.0077	0.0396	0.0415	11.4
60	1.0171	0.8913	0.1258	0.0071	0.0432	0.0454	9.1
65	1.0145	0.8881	0.1264	0.0066	0.0467	0.0492	8.4
70	1.0117	0.8848	0.1269	0.0062	0.0499	0.0527	7.1
75	1.0086	0.8813	0.1273	0.0059	0.0526	0.0558	5.9
80	1.0054	0.8778	0.1276	0.0057	0.0546	0.0580	3.9

Column (4) shows that the difference in density between the skim-milk and the fat increases rather rapidly from 5° to 35°C., but from 35° to 80°C. the increase in this difference is not so marked. Column (5) shows that the viscosity decreases rather rapidly as the temperature increases up to 35° to 40°C. Thus these two factors cause the effective force, tending to separate the fat from the plasma, to increase rather rapidly with temperature up to about

35° to 40°C. but from there on the increase with temperature is not so pronounced. Still another factor which tends to make the efficiency of separation increase more rapidly with temperature

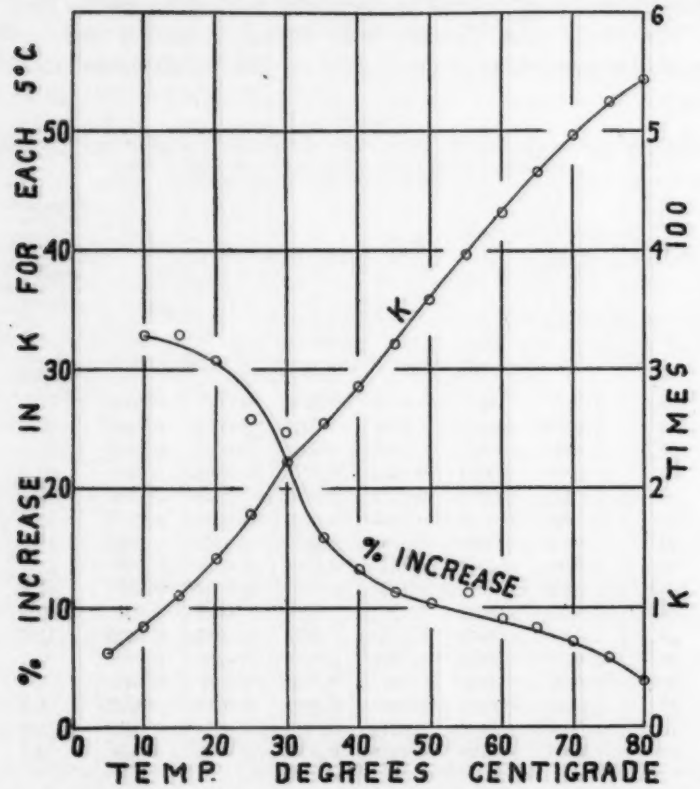

FIG. 1. INCREASE IN THE EFFECTIVE FORCE OF SEPARATION WITH TEMPERATURE AS REPRESENTED BY K, AND THE PERCENTAGE INCREASE FOR EACH 5°C. INCREMENT OF INCREASE IN TEMPERATURE

up to 35° to 40°C. is the actual expansion of the fat globules. If the size of the fat globules is measured at 5°C. their volume will be 6.2 per cent greater at 40°C. while they will increase in volume only about 3 per cent in going from 40° to 80°C. It was assumed

that the fat globules were measured at 5°C. and the effect of the increase in size of the fat globules with the increase in temperature as influencing K is given in column (7) as K^1.

The percentage increase in the constant K^1 of column (7) was calculated for each 5° increment of increase in temperature. The results are given in column (8). By increasing the temperature of separation from 5° to 10°C. the effective force tending to separate the fat from the skimmilk is increased 33 per cent. On the other hand by increasing the temperature from 40° to 45°C. the increase in force tending to separate the cream is increased only about 11 per cent. The relation between temperature and the values of K^1 is shown in figure 1. It is seen that the curve for the constant K^1 has two parts, one in which the fat is mostly solid, at the point which the fat becomes liquid, the curve breaks to a less steep slope. The effect of temperature is shown more definitely by plotting the percentage increase in K^1 for each 5°C. interval increase in temperature. Each 5°C. increase in temperature produces a marked increase in the effective force tending to separate the cream up to about 25°C. where there is a distinct break in the curve and at 35° to 45°C. the curve breaks again and tends to run more nearly horizontal. This curve shows that the effectiveness of the centrifugal force exerted, increases most markedly as to the temperature increases up to about 40°C. By increasing the temperature from 5° to 40°C. the effective force tending to separate the cream increases 380 per cent while in going from 40° to 80°C. the effective force increases only 95 per cent.

While many factors play a part in determining the temperature of cream separation, it is interesting to note that up to the temperature of 35° to 45°C. (95° to 113°F.) there is a marked increase in effective centrifugal force tending to separate the fat from the skimmilk while above this temperature the increase is not so great. Perhaps the relationship pointed out here is one of the reasons for the selection of a separation temperature near 40°C. when a recovery of the fat is the object of the separation.

There is a growing tendency to separate milk at lower and lower temperatures in order to obtain cream with a greater body. The results in table 1 indicate that if the temperature of separa-

tion is decreased from 40°C. (104°F.) to 25°C. (77°F.) a decrease of about 39 per cent in the effective force tending to separate the cream will occur.

SUMMARY

The effective centrifugal force tending to separate the fat from the skimmilk in a cream separator, operated at constant speed and rate of flow of milk, increases markedly as the temperature of the milk is increased up to 35° to 45°C. (95° to 113°F.), above this temperature the increase is much less pronounced.

This increase in effective force is due to the increase in the difference in density between the fat and the plasma, and to the decrease in viscosity of the plasma.

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GROWTH IN WEIGHT OF GUERNSEY COWS AFTER THE AGE OF TWO YEARS*

CHARLES W. TURNER

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The growth of lactating Jersey cattle, as indicated by changes in live weight, was reported in a previous communication (1). It was found that after the age of two years the course of growth of the Jersey cow was noncyclic and the rate of decline in growth was exponential, i.e., the percentage decline in the rate of growth, as measured by weight, in unit time was constant.

The present paper is for the purpose of presenting data covering the same period in the growth of a second breed of dairy cattle, namely, the Guernsey, and to show that the characteristics of the growth curve are essentially the same as those of the Jersey breed.

In table 1 will be found the frequency distribution of the animals included in the study. Included in the table are all Advanced Registry Guernsey cows for which weight data are available. While the number is limited it is believed to be a representative population of such animals. It will be noted that the calculated normal frequency is in good agreement with the observed frequencies.

As the weight data on the cows were sent to the Guernsey Cattle Club at the close of the year's production, the weights either actual or carefully estimated were taken at the close of the lactation period. The age of the animals in this case is the age at the time the weights were taken rather than the age at commencement of test given in the previous paper. For purposes of comparison with the Jersey growth curve, a correction of one year should be made.

The statistical constants derived from table 1 are presented in table 2. The mean observed weights at half-year intervals with their probable errors may be noted. In figure 1, is shown the

* Received for publication February 20, 1928.

TABLE 1

Table of age and weight of Guernsey cattle

WEIGHT CLASSES	AGE CLASSES, YEARS AT CLOSE OF LACTATION PERIOD																							TOTAL	CALCULATED NORMAL FREQUENCY DISTRIBUTION
	2 to 2.5	2.5 to 3.0	3.0 to 3.5	3.5 to 4.0	4.0 to 4.5	4.5 to 5.0	5.0 to 5.5	5.5 to 6.0	6.0 to 6.5	6.5 to 7.0	7.0 to 7.5	7.5 to 8.0	8.0 to 8.5	8.5 to 9.0	9.0 to 9.5	9.5 to 10.0	10.0 to 10.5	10.5 to 11.0	11.0 to 11.5	11.5 to 12.0	12.0 to 12.5	12.5 to 13.0	13.0 to 13.5	13.5 to 14.0		
pounds																									
600– 649			1	1																				2	2
650– 699	1	1	1	0		1		1										1						6	6
700– 749		1	9	3	1	4	1	1						1				0						21	16
750– 799		1	15	4	2	1	1	2						1				0						27	44
800– 849		5	44	17	6	4	3	1	2	4				1		1		0						88	89
850– 899		7	50	31	9	5	4	3	3	3	2		1	1	1	1		0						121	159
900– 949		11	116	51	32	23	15	13	4	5	3	4	6	4	2	3		1		1			1	295	215
950– 999		12	133	60	35	25	11	15	11	9	4	7	6	5	3	3	1	0	4	1		1	0	346	342
1,000–1,049		13	155	70	53	35	36	23	19	16	13	13	4	3	4	1	2	3	0	1		0	0	464	404
1,050–1,099		6	100	57	40	37	25	19	20	9	6	10	4	3	2	7	3	3	1	1	2	2	2	359	414
1,100–1,149		3	85	64	41	33	33	24	22	26	18	9	10	8	3	4	6	4	2	1	2	1	0	399	366
1,150–1,199		3	31	20	23	24	24	18	18	11	9	7	5	5	1	4	5	0	1	1	0	1	1	212	281
1,200–1,249			19	25	17	19	29	15	15	16	12	10	5	14	2	3	4	0	1	0	3	1		212	186
1,250–1,299			8	4	10	11	7	12	7	6	7	6	1	1	3	3		1	1	0	2	1		92	105
1,300–1,349			7	7	11	2	4	4	2	7	2	1	2	2	1	1		2	0	0				55	52
1,350–1,399			0	1	0	2	1	3	1	2	3	2	1	2	1				0	1				20	22
1,400–1,449			1		2	1	3	1	2	1	2	1	0		0				1					15	8
1,450–1,499								0	0	1		0	0		1									2	2
1,500–1,549						1		1	1			1	1											5	1
	1	63	775	415	282	228	197	156	127	116	81	71	46	51	24	31	21	15	11	7	9	7	4	3	2,741	

course of growth after two years until maturity. The smoothed curve was computed from the exponential equation

$$W_t = A\,(1 - e^{-kt}) \qquad (1)$$

where W_t is the mean live weight at any age t, A the weight of the animal at maturity, e the base of natural logarithms, and k

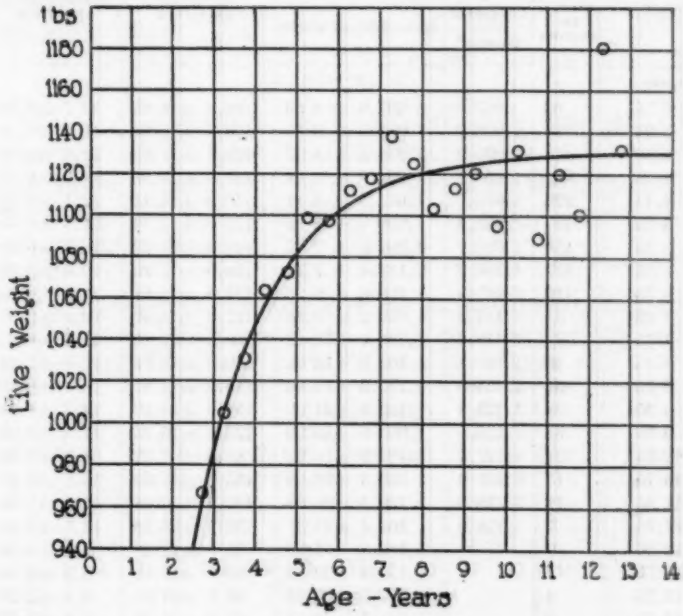

FIG. 1. RELATION BETWEEN AGE AND WEIGHT OF GUERNSEY COWS AFTER THE AGE OF TWO YEARS

The circles represent the observed values; the smooth line is the fitted curve of the equation $W_t = 1130\,(1 - e^{-0.55t})$ when W_t is the mean live weight at any age t.

the parameter indicating the rate of decline of the growth limiting reaction.

When the parameters A and k are determined, the equation takes the form

$$W_t = 1130\,(1 - e^{-0.55t}) \qquad (2)$$

where t is the age from conception. The birth age equals (t + 0.77) for the calf is carried in utero 0.77 years. The fit of the

TABLE 2

Growth of the Guernsey cow

AGE	NUMBER OF ANIMALS INCLUDED	LIVE WEIGHT		STANDARD DEVIATION	COEFFICIENT OF VARIATION
		Computed from formula*	Mean observed weight		
years					
2.75	63	967.0	967.9 ± 8.83	104.0 ± 6.25	10.7 ±0.65
3.25	775	1,006.2	1,005.3 ± 2.75	113.3 ± 1.94	11.3 ±0.19
3.75	415	1,035.9	1,030.4 ± 4.29	129.5 ± 3.03	12.6 ±0.29
4.25	282	1,058.6	1,064.9 ± 4.94	123.0 ± 3.49	11.6 ±0.33
4.75	228	1,075.7	1,071.5 ± 5.81	130.0 ± 4.11	12.1 ±0.38
5.25	197	1,088.8	1,099.4 ± 5.86	122.0 ± 4.14	11.1 ±0.38
5.75	156	1,098.7	1,097.8 ± 7.45	138.0 ± 5.27	12.6 ±0.48
6.25	127	1,106.2	1,112.4 ± 7.35	120.0 ± 5.20	10.8 ±0.47
6.75	116	1,111.9	1,118.6 ± 8.36	133.5 ± 5.91	11.9 ±0.53
7.25	81	1,116.3	1,139.2 ± 9.18	122.5 ± 6.49	10.8 ±0.57
7.75	71	1,119.6	1,125.0 ±10.12	126.5 ± 7.16	11.2 ±0.64
8.25	46	1,122.1	1,103.3 ±13.81	139.0 ± 9.76	12.6 ±0.88
8.75	51	1,124.0	1,113.3 ±13.96	148.0 ± 9.87	13.3 ±0.89
9.25	24	1,125.4	1,120.8 ±21.20	154.0 ±14.99	13.7 ±1.34
9.75	31	1,126.5	1,095.9 ±15.20	125.5 ±10.75	11.5 ±0.98
10.25	21	1,127.4	1,132.2 ±10.21	69.5 ± 7.22	6.1 ±0.64
10.75	15	1,128.0	1,088.3 ±26.94	155.0 ±19.05	14.2 ±1.75
11.25	11	1,128.5	1,120.5 ±28.54	140.5 ±20.18	12.5 ±1.80
11.75	7	1,128.9	1,101.4 ±35.51	139.5 ±25.10	12.7 ±2.28
12.25	9		1,180.6 ±17.09	76.0 ±12.08	6.4 ±1.02
12.75	7		1,132.2 ±23.93	94.0 ±16.92	8.3 ±1.49
13.25	4		1,062.5 ±30.18	89.5 ±21.34	8.4 ±2.01
13.75	3		1,241.7 ± 9.14	23.6 ± 6.46	1.9 ±0.52
Total.....	2,740		1,057.6 ± 1.69	131.0 ± 1.19	12.4 ±0.11

* Computed from the equation $W_t = 1130\ (1 - e^{-0.55t})$.

equation is good where the data are numerous enough to be reliable.

The equation for the growth of the Jersey cow was

$$W_t = 960\ (1 - e^{-0.60t})$$

It will be noted that the average mature weight of the Guernsey Advanced Registry cow is 170 pounds greater than the Jersey, whereas, the value of k is 0.05 less. The difference in the latter indicates that the rate of growth of the Jersey cow is slightly greater than the rate of growth of the Guernsey cow. However, no statistical measure of the reliability of k is available. It is possible, therefore, that the small observed difference in k may not be significant.

SUMMARY

Data are presented on the change of weight with age of the Guernsey cow. It was shown that from the age of first calving at about two years, until the age of maximum body weight, the course of growth in body weight can be accurately represented by an exponential equation.

It is a pleasure to acknowledge the indebtedness of the writer to Mr. C. M. Cummings of the Advanced Registry Division of the American Guernsey Cattle Club for the original data.

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LIPINS AND STEROLS AS SOURCES OF ERROR IN THE ESTIMATION OF FAT IN BUTTERMILK BY ETHER EXTRACTION METHODS*

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The earliest authentic method of determining the percentage fat content of dairy products was the so-called gravimetric, in which the fatty substances were extracted by means of fat solvents, an aliquot or all of the solvents evaporated, and the amount of fatty substances measured by weighing. Numerous methods of procedure were suggested, all of which were essentially the same in principle. In 1890 the development of the Babcock test (1) offered a more rapid means of estimating the fat content of milk. In the following year Myers (2) made comparisons which indicated that in testing buttermilk Babcock's method gave results considerably lower than those obtained by the Adams gravimetric. Because the gravimetric method was considered as standard, the Babcock results were looked upon as too low. Later the gravimetric procedure of Roese (3), improved by Gottlieb (4), and known as the Roese-Gottlieb method was made official by the Association of Official Agricultural Chemists. Europe has made greater use of this method than has this country, but throughout the world it has been considered to be the only entirely accurate test.

The acceptance of the Babcock method in America as a standard means of analysis led to its widespread use in practical lines of work, and it was considered reliable even for determining the fat content of buttermilk. Hunziker (5), in his first edition of "The Butter Industry," states that, "in a properly operated creamery, where the conditions relative to exhaustiveness of churning are carefully watched, the buttermilk seldom exceeds 0.2 per cent. . . . ." Guthrie (6) makes no statement relative

* Received for publication February 24, 1928. Published with the approval of the Director as Paper No. 767. Journal Series, Minnesota Experiment Station.

to the average fat content of buttermilk, but recommends the Babcock test as a means of determining the amount of fat lost in this product.

By 1921, however, gravimetric analyses of buttermilk in the laboratory of the American Association of Creamery Buttermakers had indicated that the fat content was considerably higher than can be estimated by the Babcock method. On the assumption that the gravimetric method yields correct results a modified Babcock method was devised at the American Association laboratory (7) which was named the American Association test, later known as the butyl alcohol test. This method gave results agreeing quite closely with those obtained by the gravimetric procedure. In 1925 the American Association test was accepted by the Dairy Division, University of Minnesota as the best one for use in creameries in testing their buttermilk. This acceptance was based on the same assumption that the American Association chemist made, and came as a result of numerous favorable comparisons between the American Association and gravimetric methods. In his later edition Hunziker (8) also recommends either a modification of the Babcock or an ether extraction method. McKay and Larsen (9) favor the American Association test.

LECITHIN AS A SOURCE OF ERROR

In the spring of 1927, while studying a different problem, one of us noticed that when powdered buttermilk is thoroughly extracted with alcohol large quantities of lecithin are removed from the buttermilk. A continuation of this work indicated that buttermilk contains much more lecithin than any of the other milk products. On reviewing the literature pertaining to the lecithin content of milk products we found that this fact had been observed at an early date but had not been considered in the more recent literature.

Dornic and Daire (10) state that buttermilk contains a higher percentage of lecithin than does any other milk product with the possible exception of cream. In this regard they cite and corroborate the work of Bordas and Racekowski (11). Dornic

and Daire (10) offer an explanation for the concentration of lecithin in buttermilk by pointing out that it is very probable that lecithin made up part of the famous "Slimmen-membran" of Storch; and that during churning, which brings the union of the fat globules, this "Slimmen-membran" disengages itself and is found later in the buttermilk. This explanation is supported by the work of Palmer and Samuelson (13) who washed fat globules and their so-called membranes free of serum by repeated dilution with water and reseparation. The buttermilk resulting from the churning of such cream was found to contain a mixture of phosphatides. It is likely that lecithin constituted a large portion of these phosphatides.

The facts and theories just pointed out suggest a reason for the disagreement between results of various methods of estimating fat content of buttermilk when applied to single samples. Lecithin as well as other lipins is soluble in ether. Consequently ether extraction as specified in the gravimetric method of estimating the fat content of dairy products may include not only fat but also lecithin in the extract. Obviously if this is the case then the gravimetric method yields results which are too high by the amount of lecithin, or other phospholipins present. The Babcock method, which always yields lower results for buttermilk than the gravimetric, may not include lecithin in the fat column. Storch (12) states that part of the "Slimmen-membran" is included in the extract obtained by the Roese-Gottlieb method causing this method to yield higher results than the soxhlet. Lecithin may have been responsible for this observation.

If the error just discussed occurs it may be expected to be more evident in connection with buttermilk than with other products because of (1) its relatively high lecithin content and (2) its low fat content.

STEROLS AS AS SOURCE OF ERROR

If the explanation for the concentration of lecithin in buttermilk lies in its disengagement from the surface of the fat globules in churning then another possible error in the gravimetric method can be suggested. It has been reported by Fox and Gardner

(14) that the sterol content of milk is roughly in proportion to the fat content. The probability that the sterols are concentrated at the surface of the fat globules is strengthened by the report of the above authors that the ratio of cholesterol to fat is greater in milk than in butter. Further evidence is supplied by Wacker and Beck (15) who show that in skimmilk the greater part of the cholesterol follows the cream fraction. This suggests that the cholesterol, and possibly other sterols, must be present in buttermilk in greater percentages than in milk, for the sterols may then be expected to disengage from the fat during churning in the same manner suggested for lecithin.

The sterols bear no close chemical relationship to fat aside from the fact that they may be dissolved by the same solvents. It is to be expected, therefore, that the gravimetric method in any of its variations which call for the extraction of fat from milk with ether will include the sterols with the fat in the resulting extract. On this basis the gravimetric method may be expected to yield results which are too high by the amount of the sterols present in the sample analyzed.

EXPERIMENTAL

Errors in the gravimetric method due to lecithin. In approaching this problem an attempt was made to determine the amount of lecithin occurring in the alcohol-ether-petroleum ether extract of buttermilk extracted according to the Roese-Gottlieb directions. Macleans's (16) statement that no satisfactory method is available for the quantitative determination of lecithin in the presence of fat was substantiated by us. It was found impossible to precipitate lecithin quantitatively from its ether solutions in the presence of fat, although a copious precipitate resulting from the addition of acetone to such solutions of the extract from buttermilks demonstrated that considerable quantities of lecithin were always present. The various methods of determining the organic phosphorus of such extracts and calculating the quantity of lecithin from it are open to at least two criticisms. First, as pointed out by Maclean (16), a certain amount of inorganic phosphorus is usually included in the extract due to its solubility in the

solvents used. Second, as suggested by Grimmer (17), we have no knowledge of what fatty acids are present in the lecithin molecule occurring in milk, and until this is determined we are not justified in using any factor for converting percentage phosphorus to lecithin.

TABLE 1

Results of various methods of fat estimation applied to synthetic milks to which fat alone was added

MILK NUMBER	SAMPLE NUMBER	FAT ADDED	"FAT" ESTIMATION BY			
			Gravimetric method	Butyl alcohol method	Babcock method (skimmilk bottle)	Babcock method (whole milk bottle)
		per cent	*per cent*	*per cent*	*per cent*	*per cent*
A	1	0.0000	0.0000	0.00	0.00	0.00
A	2	0.1700	0.1583	0.04	0.05	
B	3	0.0000	0.0000	0.00	0.00	0.00
B	4	0.4300	0.3864	0.22	0.22	0.43
C	5	0.1497	0.1426	0.05	0.10	0.23
C	6	0.3526	0.3508	0.29	0.24	0.40
C	7	0.5964	0.5979	0.60	0.32	0.60
D	8		0.1579	0.13	0.10	0.32
D	9		0.3017	0.30	0.24	0.40

TABLE 2

Results of various methods of fat estimation applied to synthetic milks to which lecithin alone was added

MILK NUMBER	SAMPLE NUMBER	LECITHIN ADDED	"FAT" ESTIMATION BY			
			Gravimetric method	Butyl alcohol method	Babcock method (skimmilk bottle)	Babcock method (whole milk bottle)
		per cent	*per cent*	*per cent*	*per cent*	*per cent*
C	10	0.1981	0.2095	0.11	0.00	0.00
C	11	0.4000*	0.3153	0.29	0.00	0.00
D	12		0.1698	0.21	0.01	0.00
D	13		0.3006	0.44	0.04	0.00

* In shaking this sample to dissolve the lecithin the flask was broken and a part of its contents lost. This undoubtedly accounts for the failure of the gravimetric results to agree with the calculated amount present.

Behavior of lecithin in testing. Because of the lack of an accurate means of determining the percentage of lecithin contained in buttermilk, it was necessary to approach the problem from a different angle. Inasmuch as one of us had isolated lecithin from buttermilk, and purified it according to the directions of Maclean (16), it was proposed that by mixing known quantities of this material in a milk containing either no fat, or a known quantity of fat, it would be possible to observe its behavior when subjected to the various, common methods of determining the percentage fat content of milk. For this purpose a synthetic

TABLE 3

Results of various methods of fat estimation applied to synthetic milks to which both fat and lecithin were added

MILK NUMBER	SAMPLE NUMBER	FAT ADDED	LECITHIN ADDED	SUM OF FAT AND LECITHIN ADDED	"FAT" ESTIMATION BY			
					Gravimetric method	Butyl alcohol method	Babcock method (skimmilk bottle)	Babcock method (whole milk bottle)
		per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
B	14	0.4300	0.4700	0.9000	0.8384	0.70	0.33	
C	15	0.1497	0.2000	0.3497	0.2887	0.26	0.10	0.30
C	16	0.3524	0.4000	0.7524	0.7595	0.73	0.32	0.32
C	17	0.5964	0.3000	0.8964	0.8263	0.94	0.51	0.63
E	18	0.2467*	0.2286*	0.4753*	0.4753	0.41	0.22	0.25

* These results calculated from the known fat content of 0.2467 per cent and the gravimetric test of 0.4753.

milk was prepared according to the directions of Clark (18). To portions of this milk additions were made of known quantities of fat, to others known quantities of lecithin, and to others known quantities of both fat and lecithin. As a check the synthetic milk without addition of fat or lecithin was also tested. The results of this work was recorded in tables 1, 2 and 3.

The methods employed for testing these products included the gravimetric, American Association or butyl alcohol and the Babcock. For the latter method results were obtained for both the whole milk and skimmed milk test bottles. All analyses were made in duplicate.

Table 1 shows the results of check tests on the synthetic milks made previous to the addition of either fat or lecithin, and also, results of tests on the same milks to which known quantities of fat had been added.

In table 2 are presented the results of the various methods of fat determination applied to synthetic milks to which known quantities of lecithin had been added.

In table 3 are presented results of the various methods of fat percentage determination applied to synthetic milks to which known quantities of both fat and lecithin had been added. These milks are thought by the authors to imitate very closely the conditions actually existing in buttermilk.

The technique of adding these substances to the synthetic milk was faulty in the cases of milks "A" and "B" as is evidenced by the disagreement between the amounts calculated to be present and the percentage found by the gravimetric method. For this reason it is the opinion of the authors that the gravimetric method represents more nearly the true fat and true lecithin content of these samples than do the calculated percentages. In the case of milk "C," however, a more accurate technique was employed, by weighing these substances on a small tin container and adding container and all to the milk, and it is seen that the gravimetric and calculated percentages agree satisfactorily. The results with milk "C" showed that the gravimetric method is accurate for determining fat or lecithin alone and consequently the gravimetric percentage is used for milks "D" and "E" as a measure of the amounts of these substances present. This was particularly necessary for milk "E" because the emulsification of the fat in this sample was accomplished by means of homogenization, whereas with the other samples it was done by shaking.

Lecithin content of buttermilk. As previously stated we were unable to determine accurately the percentage of lecithin present in our buttermilk because of inability to find an accurate and reliable method. Although the work with synthetic milk did not evolve any such method it did furnish us with a means of roughly measuring the lecithin content of buttermilk. It has been shown that the Babcock method estimates fat but not leci-

thin, whereas the gravimetric method shows both. It is therefore logical to expect that the difference between the gravimetric and Babcock analyses of a single sample of buttermilk should show the approximate percentage of lecithin present. A glance at the figures in table 4, which are calculated from the results presented in table 3, show that this calculation does give the approximate percentage of lecithin contained in these samples of synthetic milk. On this basis the percentage of lecithin in buttermilk was studied.

For this phase of the work we prefer to substitute the word "lipin" for "lecithin," because it is possible that not all of the phosphatides of milk or buttermilk are lecithin as Koch and Woods (19) state that milk contains two phospholipins, lecithin

TABLE 4

Difference between gravimetric and Babcock results as a measure of lecithin content

MILK NUMBER	SAMPLE NUMBER	LECITHIN ADDED	LECITHIN CALCULATED, GRAVIMETRIC MINUS BABCOCK
		per cent	*per cent*
B	14	0.47	0.5084
C	15	0.20	0.1887
C	16	0.40	0.4395
C	17	0.30	0.3163

and cephalin in approximately equal quantities. The word "lipin" is here used with the meaning applied to it by Maclean (16).

If we accept the suggestion of Dornic and Daire (10) that the lecithin is concentrated at the surface of the fat globules then one should expect that buttermilk from cream high in fat would contain a higher percentage of lipins than buttermilk from a cream low in fat. We therefore obtained a cream containing 52 per cent fat and churned part of it. The other part was diluted with skimmed milk to test 26 per cent and churned. The results of estimating the lipin content of buttermilks from these creams by the differences between the gravimetric and Babcock tests showed 0.59 per cent for the first and 0.36 for the second.

To confirm this result another trial was conducted in which the following buttermilks were tested:

1. From 22 per cent cream prepared by diluting 45 per cent cream with skimmed milk.
2. From 45 per cent cream.
3. From 34 per cent cream prepared by diluting 68 per cent cream with buttermilk no. 1.
4. From 68 per cent cream.

The results of this trial are recorded in table 5.

The difference between the gravimetric and Babcock results, which we believe is accounted for by the presence of lipins, is

TABLE 5

Lipin content of buttermilks from creams of different fat content as measured by difference between gravimetric and Babcock results

BUTTERMILK NUMBER	GRAVIMETRIC ANALYSES	BABCOCK ANALYSES	CALCULATED LIPINS
	per cent	*per cent*	*per cent*
1	0.5131	0.12	0.3931
2	1.2742	0.70*	0.5742
3	9.6652	9.00*	0.6652
4	2.6768	1.80*	0.8768

* Determined in whole milk test bottle, read with glymol.

seen to increase with the increase in the fat content of the cream from which the buttermilks were churned. We believe this indicates that our method of determining the approximate lipin content of buttermilk is roughly correct. Assuming it to be correct we find the lipin content of buttermilk to be between 0.36 and 0.87 per cent. So high a percentage of lipins in buttermilk as indicated here is sufficient to cause the gravimetric method to yield results for average buttermilk which are fully double the percentage of fat present.

Errors in the gravimetric method due to sterols. As we have already pointed out it is possible that an error in the gravimetric results may occur due to sterols. Sterols differ sufficiently from butterfat that if a mixture of fat and sterols are subjected to

saponification under proper conditions the fat, and likewise the lecithin if present, may be transformed into soap while the sterols are not changed. The determination of the non-saponifiable matter therefore offers a means of detecting not only the amount of sterols, but all the non-saponifiable materials extracted from milk by the solvents commonly used in the gravimetric determinations of fat percentage.

Not enough results have been secured by us to conclusively settle this question. We offer our determinations only as evidence that this error exists, and with the hope that other investigators may attempt to verify the results.

For this work it was necessary to have relatively large quantities of ether extract of buttermilk on which to make determina-

TABLE 6

Error in gravimetric method due to non-saponifiable matter in ether extract

BUTTERMILK SAMPLE NUMBER	"FAT" BY GRAVIMETRIC METHOD	NON-SAPONIFIABLE MATTER IN BUTTERMILK	NON-SAPONIFIABLE MATTER IN ETHER EXTRACT
	per cent	*per cent*	*per cent*
1	1.3130	0.0236	1.838
2	1.2742	0.0195	1.530
3	0.6480	0.0107	1.665
4	0.6815	0.0284	4.180

tions. Consequently, 100-gram quantities of buttermilk were extracted with alcohol, ether and petroleum ether in separatory funnels of a liter capacity. This process was repeated with each sample of buttermilk until 5 grams of extract were obtained. The official Roese-Gottlieb directions call for the use of 1.5 cc. of ammonia, 10 cc. of ethyl alcohol, 25 cc. of ethyl ether and 25 cc. of petroleum ether for 10 grams of buttermilk. Accordingly 10 times these amounts were used for this extraction. It was deemed unnecessary to reëxtract as required in the official directions because the yield on the second extraction was too small to warrant the use of such large quantities of solvents. It was assumed that the single extraction would yield materials which were representative of the entire amount of alcohol-ether soluble material present in buttermilk.

The percentage non-saponifiable matter contained in these extracts was determined according to the method described by the Association of Official Agricultural Chemists. The results of these studies are presented in table 6. A qualitative study of this non-saponifiable matter indicated that it was made up almost entirely of cholesterol. The cholesterol content of milk has been reported by Dennis and Minot (20) to be between 10.5 and 17.6 mgm. per 100 cc., while Fox and Gardner (14) report the amount to be 11.4 to 17.3 mgm. per 100 cc. The amount of non-saponifiable matter in butterfat centrifuged or churned from whole milk is usually very low. There can be little doubt that buttermilk contains non-saponifiable materials, chiefly cholesterol, which are responsible for an error of about 0.02 per cent in any gravimetric method which requires the extraction of the product with ether, alcohol, and petroleum ether.

DISCUSSION

The gravimetric method. Our results show that the gravimetric method of fat determination, when applied to buttermilk, gives results which are higher than the true fat content by the amount of non-saponifiable matter and lecithin present in the product tested. Tables 2 and 3 show this definitely for it is seen from table 2 that the method is as accurate for determining the percentage of lecithin as it is for determining the percentage of fat. Results recorded in table 3 further show that, rather than determining the percentage of fat in samples containing both fat and lecithin, it estimates the total of the percentages of fat and lecithin, within reasonable limits of experimental error.

The American Association method. Inasmuch as the American Association or butyl alcohol test determines the percentages of lecithin in synthetic milk, as shown by table 2, and determines roughly the total of the percentages of fat and lecithin when both are present it is inaccurate. The only reason for the use of this method in the past has been the close agreement of its results with those obtained by the gravimetric method. This was sufficient reason for its use, assuming the gravimetric or official method to yield correct results. On this assumption one of us

has repeatedly recommended the American Association method during the past few years for testing buttermilk. The results of the work reported in this paper, however, are considered by us to show beyond question that the use of this method should be discontinued.

The Babcock method. The Babcock method of fat percentage determination is shown by our results to be most accurate for the testing of a product such as buttermilk, containing roughly as much lecithin as fat. It is free from the criticism that we make of the gravimetric and American Association methods. It does fail to give entirely accurate results, however, particularly in the testing of buttermilks below 0.3 per cent fat, in which cases its results are often considerably too low. To use the whole milk test bottle yields results which are usually too high due to the inclusion of the meniscus in the reading. It will be noticed that an average of the skimmed and whole milk bottle results agrees fairly well with the actual fat content in most cases, but we do not recommend this as an accurate means of determination of the fat content of buttermilk because it averages two opposite errors.

The failure of the Babcock method to estimate all the fat in the cases cited above recalls the work of Farrington (21) who was the first to report that by using more sulphuric acid and centrifuging for a full five minutes at the prescribed speed higher results may be obtained. Our studies with synthetic milk explain why this happens for if we subject a test of synthetic milk, to which lecithin but no fat has been added, to these conditions we obtain a dark but definite column in the neck of the bottle which is undoubtedly either lecithin or its decomposition products. At one time we subjected some Babcock tests of buttermilk to extremely high centrifugal force for prolonged periods and obtained results which agreed closely with the gravimetric results. It is evident, therefore, that the so-called "rigorous method" of Farrington may include some lecithin in the fat column along with the fat. This possibility is strengthened by the evidence supplied by Coriat (22) that lecithin is not easily hydrolized by acids. If this is true then a part of the lecithin exists in the Babcock test acid mixture without change.

The Gerber method. It is well known that in the European countries the Babcock method has never been accepted as a standard "quick" test. Instead, these countries have adopted the Gerber method which makes use of amyl alcohol in much the same manner that the American Association test uses butyl alcohol. Amyl alcohol differs from butyl in that it is the next higher member of the series. Its properties are little different from those of butyl alcohol and its effect when used in a milk test such as the Gerber is essentially the same as that of butyl alcohol. The authors are therefore of the opinion that the Gerber method also yields incorrect results for buttermilk.

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A COMPARISON OF CERTAIN METHODS FOR DETERMINING THE SANITARY QUALITY OF ICE CREAM*

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INTRODUCTION

From a sanitary point of view the production of all dairy foods requires the solution of two problems, viz.: (*a*) to avoid the danger of conveying disease, and (*b*) to avoid unsanitary conditions. Sanitarians have devoted especial attention to the production of safe and clean milk, but they have not given the same consideration to the manufacture of ice cream. Not only does the use of ice cream involve the same dangers as the use of milk but, in addition, those that may be introduced while dispensing it. Frequently ice cream dippers, dishes and hands are washed in the same water, which is used without heat or sterilizing agents and changed at infrequent intervals. Nor is the problem of eliminating unsanitary conditions less important than in milk, even if undesirable flavors can be successfully hidden by sugar, essences, fruits or nuts. Responsibility for these conditions seems to rest with the scientists who have failed to provide the necessary technic for determining unsanitary conditions; with the sanitarians who have been less exacting in their requirements; and with the legislators who have placed undue emphasis on the butter fat content and too little on the manner of handling of the product.

There are three bacteriological tests available for determining the sanitary quality of ice cream: (*a*) total count of bacteria; (*b*) colon group test; and (*c*) anaerobic spore test. At present the total count of bacteria is used to the exclusion of the other two, and commonly not even this test is required. It would seem

* Received for publication February 27, 1928.

that ice cream merits greater consideration by sanitarians than it has received, and that a comparative study of the methods available for determining its sanitary quality is highly desirable.

HISTORICAL

In the past investigators seem to have centered their efforts chiefly upon the bacterial count of ice cream. As early as 1904, Buchan (1) suggested that ice cream should not contain more than 1,000,000 organisms per cubic centimeter. Fay (2) believed that ice cream could be produced in Kansas with a bacterial count of 100,000 or less if pasteurization and care in handling were practiced. The next year Fay and Olson (3) went a step farther and declared it practical to produce ice cream containing less than 100,000 bacteria per gram. In Michigan, Fabian made a number of helpful studies: In 1920 he (4) suggested a score card for ice cream plants; with Cromley in 1923 he (5) studied the influence of manufacturing operations on the bacterial count of ice cream; in 1926 he (6) showed the relation of ice cream to disease epidemics; and the same year he (7) suggested a bacteriological standard of 100,000 or less per gram. Apparently only one state, California (8), has placed a legal standard upon the bacterial count of ice cream, namely, a maximum count of 150,000 per gram. The colon group determination has not been employed for ice cream, and the anaerobic spore test devised for milk has never been attempted.

The opinion voiced editorially (9) in 1920 in the Journal of the American Medical Association still seems applicable: "Is it unfair to say that better standards should be maintained in this industry which has heretofore often escaped suspicion because of a mistaken belief in the bactericidal effect of cold?"

METHODS EMPLOYED

The samples were placed in an incubator at 37°C. for about twenty minutes to melt the cream so that it could be measured with graduated pipettes for making the necessary dilutions and cultures. All samples were analyzed within an hour after they were dispensed.

For the total count a dilution of 1:10,000 was used. Plating a larger number of dilutions would have given more accurate results. Duplicate plates were made, incubated forty-eight hours at 37°C., and the colonies counted by means of a hand lens.

Since those who have made the most intensive studies of ice cream agree that a standard of 100,000 or less could readily be maintained, and since California has actually adopted 150,000 as a permissible maximum, we felt that 500,000 would furnish a very liberal basis for condemnation purposes. Accordingly this figure was arbitrarily applied to the results.

For the colon group determination the dilutions employed were 1:10, 1:100, to 1:1,000,000. Enrichment tubes containing 1 per cent lactose bouillon were inoculated with 1 cc. portions from each dilution. After enrichment, endo agar plates were made from tubes showing 10 per cent or more gas. Typical colonies were fished and confirmed according to the American Public Health Association Standard Methods for Water Analysis.

There being no set standard for the permissible number of colon group bacteria allowable in ice cream, and none suggested so far as we were aware, we finally decided that a density of 10,000 per cubic centimeters would afford a liberal limit which was arbitrarily adopted.

For the anaerobic spore test, 1 cc. of the ice cream was placed in each of five sterile tubes containing vaseline and about 10 cc. of sterile water added. These tubes were heated at 80°C. for ten minutes to kill vegetative bacteria, expel oxygen, and bring the vaseline to the surface thus making the anaerobic seal. All cultures were incubated at 37°C. for 96 hours. This was essentially the technic described by Weinzirl (10) for milk work, the 1 cc. of ice cream being substituted for 5 cc. of milk. For purposes of condemnation, an arbitrary standard based upon our limited experience, was set up. It appeared probable that three positives out of five 1 cc. portions would catch excessive pollution and eliminate anaerobes added with the sugar.

RESULTS OBTAINED

By the methods outlined above 124 samples of ice cream, including all the common varieties, were tested. Of these samples 24 came directly from the factory, and 100 from dispensers. The data are too bulky to be included in full, but summaries will be given for the separate tests.

The factory samples gave very low counts, 100 per cent of them being less than 500,000. Of the dispensers' samples only 31 per cent fell below 500,000, while 69 per cent were above. (See table 1.) Since most of the ice cream dispensed was produced in the factories considered, and since 94 per cent of the samples were pasteurized, it appears obvious that there is a tremendous

TABLE 1

Summary of results when ice cream was tested by the total count method

SOURCE OF SAMPLES	NUMBER OF SAMPLES	COUNT LESS THAN 100,000	COUNT MORE THAN				
			100,000	500,000	1,000,000	10,000,000	100,000,000
Factory	24	21	3	0	0	0	0
Dispenser	100	4	96	69	37	8	4
Total	124	25	99	69	37	8	4

increase after the product left the factories due either to multiplication or contamination or both.

This difference between factory and shop samples was a great surprise to us, but according to the literature, it appears that similar results were obtained by other investigators. It seems quite clear that the factories can readily meet a standard of 500,000, especially if they are permitted to pasteurize their product. For the dispensers to meet this standard it would require radical improvement in their methods.

Assuming that the presence of colon group in a dilution of 1:10 means a density of 10 per cubic centimeter, etc., and recalling that the arbitrary standard adopted was a density of 10,000 per cubic centimeter, we find that 92 per cent of the factory

samples meet this requirement, while only 68 per cent of the dispensers' samples meet it. (See table 2.) This shows a disparity between the two sources similar to that shown by the total count, but the difference is less marked, probably justly so. The data also seem to indicate that the colon group test might prove valuable for checking the sanitary methods of the dispensers.

The anaerobic spore test was devised for the purpose of determining contamination in milk. (See table 3.) Obviously it

TABLE 2

Summary of results when ice cream was tested by the colon group determination

SOURCE OF SAMPLES	NUMBER OF SAMPLES	COLON GROUP PRESENT IN DILUTION					
		1:10	1:100	1:1000	1:10,000	1:100,000	1:1,000,000
Factory	24	21	17	11	2	0	0
Dispenser	100	89	77	58	32	16	9
Total	124	110	94	69	34	16	9

TABLE 3

Summary of results when ice cream was tested by the anaerobic spore test

SOURCE OF SAMPLES	NUMBER OF SAMPLES	NUMBER OF TUBES SHOWING ANAEROBIC SPORES				
		1	2	3	4	5
Factory	24	6	5	1	1	1
Dispenser	100	75	23	14	6	5
Total	124	81	28	15	7	6

can be applied to ice cream for the same purpose. The tests recorded above give the results which in a general way parallel those of the other two methods. Again the factory samples make the better showing, but the contrast is much less marked. It is improbable that the number of anaerobic spores increases in the frozen ice cream; if this be true, then contamination during dispensing must account for the difference. Perhaps the lower percentage of condemnation, 4 and 14 per cent, is due to

the fact that this test is probably not influenced by multiplication as are total count and colon group. If so, this seems to be a distinct advantage.

On the basis of the arbitrary standards previously suggested, we find that the total count condemns more samples than either of the other two methods, and that the colon group determination condemns more than the anaerobic spore test. (See table 4.) Obviously the standards for condemnation could have been adjusted so as to reverse these figures. It is quite impossible to determine on the basis of figures like the above which method is the more accurate for determining contamination. To decide this question it would be necessary to contaminate sterile prod-

TABLE 4

Summary of results using arbitrary standards for condemnation

SOURCE OF SAMPLES	NUMBER OF SAMPLES	NUMBER OF SAMPLES CONDEMNED BY		
		Total count (500,000)	Colon group in 1:10,000	Anaerobic spores in 3 out 5, 1 cc. portions
Factory	24	0	2	1
Dispenser	100	69	32	14
Total	124	69	34	15

ucts and then apply the tests to see which gives the more accurate results. In the absence of such data we are compelled to base judgment of their relative values upon general considerations.

For determining contamination the total count and colon group determination cannot be accurate because both are affected by growth and multiplication of the bacteria present. It would seem unjust to condemn a given lot of ice cream as unduly contaminated when the high test is due largely to multiplication. These tests are inapplicable for a pasteurized product since pasteurization destroys the vegetative organisms. On the basis of these two tests, the pasteurized samples would have to be

regarded as exceptionally clean, while the unpasteurized would be highly unclean, although the reverse may have been true.

If the total count and the colon group test have any value in the case of pasteurized ice cream, this value is limited to determining the efficiency of pasteurization or the extent of subsequent contamination. If the high results obtained for the dispensers' samples are due partly to methods of handling, 94 per cent of them being pasteurized, then these two tests are worth while for this purpose at least. The anaerobic spore test also gives higher results for the dispensers' samples, 14 per cent as against 4 per cent.

As applied to ice cream the anaerobic spore test has the disadvantage of including the spore anaerobes present in sugar and possibly other products (10). One of us, Weinzirl (11), has shown that sugar commonly contains anaerobic spores to the extent of one per gram of sugar. If the ice cream contains 15 per cent of sugar, on the basis of this test there is introduced roughly an apparent error of 15 per cent. Actually the error cannot be so large under the standard assumed because the rule of "3 positives out of 5" tubes would largely eliminate this error. However, it is an error that cannot be disregarded.

SUMMARY AND CONCLUSIONS

1. A total of 124 samples of commercial ice cream were obtained from producers and retailers in Seattle and subjected to the following tests: (*a*) total count of bacteria; (*b*) colon group determination; and (*c*) anaerobic spore test.

2. The total count reveals the results of contamination and of subsequent multiplication of the bacteria introduced, but it does not distinguish between the two.

3. The colon group test functions like the total count, but it is somewhat more specific in indicating unsanitary conditions.

4. The anaerobic spore test shows unsanitary conditions only, but in the case of ice cream it fails to distinguish between the spores introduced through unsanitary conditions and those added with the sugar.

5. For freshly pasteurized products the first two methods are

useless except for controlling pasteurizing efficiency; they have distinct value for testing subsequent contamination; the last method reveals contamination in both pasteurized and unpasteurized products.

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THE EFFECT OF FLASH PASTEURIZATION OF MILK UPON THE FLAVOR AND TEXTURE OF CHEDDAR CHEESE*

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A considerable amount of cheddar cheese of poor quality is manufactured in the Western states, especially during the summer months, since proper care is not given to the milk by the producers; consequently, the supply is not uniform throughout the year, and usually varies during a season. Cheese is the only dairy product which can be manufactured in California from milk produced from herds infected with tuberculosis without pasteurization of the milk.

Due to these conditions experiments were started at the California Experiment Station at Davis in October, 1925, in order to determine the advisability of flash pasteurization at different temperatures in the cheddar cheese process. The process is not new, since there are several references in the literature. Sammis and Bruhn (1) in 1912 reported the successful manufacture of cheddar cheese from milk flash pasteurized at 160° to 165°F. for an instant. They added hydrochloric acid to the milk in order to aid the coagulation by rennet. This method evidently has not been used to any extent in commercial manufacture during recent years.

Stevenson in 1920 (2) and in 1923 (3) discussed the methods used in New Zealand, where approximately two-thirds of all cheddar cheese manufactured is from milk pasteurized by the flash method. Regenerative flash pasteurization was used, heating the milk to 160° to 165°F., and cooling to the setting temperature. Temperatures below 160°F. allowed a deterioration in the flavor of the cheese, and if above 165°F., the body and tex-

* Received for publication March 13, 1928.

ture of the cheese were injured, the result being mealy cheese. Hydrochloric acid was found to be of no assistance in aiding coagulation. The cheese made from pasteurized milk scored two to three points higher after this practice was started.

Murray (4) in 1924, states that in experiments at the Hawkesbury Agricultural College and Moruya Cooperative Cheese factory it has been found that flash pasteurization at 155°, 165° and 175°F., or holding at 145°F. for 30 minutes tends to control the fermentation of the milk to be used in cheese making, and also reduces the undesirable organisms present. The quality of the cheese was thereby improved.

Considerable experimental work using the holding method of pasteurization has been reported. Price (5) in 1927 gave a summary of this work, and also reported the results of rather extensive work at the New York Agricultural Experiment Station and recommended this method.

The flash method of pasteurization seems to be well suited to the factories operating in the Western states, and consequently the holding method was not included in the scope of this work.

EXPERIMENTAL

Use of good milk

Raw milk of good quality was selected at the University Farm Creamery platform. The bacterial counts varied from 8500 to 113,000 per milliliter, and there were no gas-forming organisms present as shown by the Wisconsin curd test. Four trials were made; 800 pounds of milk being selected each time. The milk was run into a receiving vat and was mixed thoroughly by means of a horizontal coil which operated continuously.

A check vat of cheese was made, using 400 pounds of the raw milk according to the regular methods of procedure. The remaining 400 pounds of milk were run over a forewarmer which heated the milk to 110°F., then through a horizontal flash pasteurizer of 3500 pounds capacity per hour, where it was heated from 160° to 168°F. An automatic temperature control apparatus was attached to the pasteurizer and the temperature

was held within the above range. The milk was cooled to 88°F. by flowing over a surface cooler. The sanitary pipe line from the pasteurizer to the cooler was rather long, and the milk was held at the pasteurization temperature approximately 25 seconds.

The cheese was made in the regular manner except that one ounce more rennet was used for each 1000 pounds of milk and a setting temperature of 88°F. was used. The cheese from the four lots was cured at 50°F., and scored at intervals by members of the Dairy Industry Division of the University of California,

TABLE 1

Flavor and texture scores on cheese made from milk of good quality

LOT	MILK	AGE—2 MONTHS		AGE—6 MONTHS	
		Flavor score	Texture score	Flavor score	Texture score
1	Raw	38.0	29.0	39.0	29.5
1	Pasteurized	36.5	27.5	38.5	29.0
2	Raw	38.5	29.0	36.0	29.5
2	Pasteurized	38.25	29.0	38.5	30.0
3	Raw	37.0	29.5	36.0	29.5
3	Pasteurized	36.0	29.0	37.0	29.5
4	Raw	37.5	28.0	39.0	29.0
4	Pasteurized	37.5	29.5	36.5	29.0
Average:					
Raw		37.75	28.87	37.50	29.37
Pasteurized		37.12	29.00	37.62	29.37

and by representatives of the Bureau of Dairy Industry, United States Department of Agriculture. The score card recommended by the United States Department of Agriculture was used which allows 45 points on flavor and 30 points on texture. There were no uniform criticisms on flavor and texture, and the scores are given in table 1.

Neither the scores nor the criticisms show uniform improvement or defects caused by the pasteurization. The texture was fairly uniform however, and did not seem to be affected by heating the milk.

Use of inferior milk

Milk of poor quality was selected from the creamery platform. The flavor and odor were bad, and large numbers of gas-forming organisms were shown to be present by the Wisconsin curd test. The acidity was low, however, ranging from 0.16 to 0.18 per cent. The average bacterial count on the seven lots of milk was 410,000 per milliliter, and after heating was 5100 per milliliter, giving an

TABLE 2

Flavor and texture scores on cheese made from milk of poor quality

LOT	MILK	AGE—2 MONTHS		AGE—6 MONTHS	
		Flavor score	Texture score	Flavor score	Texture score
5	Raw	34.0	27.0	32.0	27.0
5	Pasteurized	40.0	29.0	38.5	29.0
6	Raw	34.0	29.0	33.0	29.0
6	Pasteurized	40.0	29.5	39.5	29.5
7	Raw	34.5	29.0	35.0	29.0
7	Pasteurized	39.0	29.0	38.5	29.5
8	Raw	35.0	29.5	32.0	29.5
8	Pasteurized	39.0	29.5	39.0	29.5
9	Raw	34.0	29.0	34.0	29.5
9	Pasteurized	38.0	29.5	38.5	29.5
10	Raw	37.0	29.0	34.0	29.0
10	Pasteurized	38.0	29.5	40.0	29.5
11	Raw	34.5	28.0	35.0	28.5
11	Pasteurized	38.0	29.0	36.5	29.5
Average:					
Raw		34.71	28.64	33.59	28.78
Pasteurized		38.86	29.28	38.64	29.43

average efficiency of 98.76 per cent at an average temperature of 165°F.

A composite portion of 100 pounds of milk was taken for the check vats. A larger portion of the milk, 3300 pounds for each lot, was heated. The flavor and texture scores are given in table 2.

Table 2 shows improvement in the flavor score of the cheese in every case when milk of poor quality was heated, the average difference in scores being approximately four points at two

months and five points at six months. A large portion of the cheese made from raw milk was not marketable due to bitter and unclean flavors. The texture was improved by heating the milk, as the formation of gas holes was eliminated.

The average yield of the cheese manufactured from the heated milk was 9.49 pounds for each 100 pounds of milk testing 3.34 per cent butterfat. Yield was not considered in the case of the raw milk because the amount of milk used was too small to insure valuable data. The average butterfat loss in the whey from the heated milk was 0.169 per cent and from the raw milk 0.222 per cent.

TABLE 3

Flavor and texture scores on cheese made from milk pasteurized at 177°F. by the flash method

LOT	MILK	AGE—2 MONTHS		AGE—6 MONTHS	
		Flavor score	Texture score	Flavor score	Texture score
12	Pasteurized	37	28.5	36	29.0
13	Pasteurized	36	29.0	37	29.0
14	Pasteurized	37	29.0	36	29.0
15	Pasteurized	37	28.5	38	28.5
Average: Pasteurized.....		36.75	28.75	36.75	28.87

Since a minimum flash pasteurization temperature of 176°F. is recognized in the butter industry, four lots of milk were pasteurized at a temperature of 176° to 178°F. The milk was of poor quality, containing large numbers of gas forming bacteria. Check vats were not made as the foregoing data showed that the cheese made from such milk was not marketable. Four vats of milk of 2650 pounds each were made; the results are given in table 3.

Table 3 shows that cheese of fair quality could be manufactured from poor milk pasteurized at 176° to 178°F. Scorched and bitter flavors were noticeable and the texture was weak and brittle. However, the cheese was marketable, which was not the case of the raw milk cheese manufactured from similar milk.

As a result of these experiments, since July, 1926, all milk for cheddar and Monterey cheese manufacture at the University Farm Creamery has been heated by the flash method to a temperature of 160° to 170°F. The cheese at two months has a uniform mild flavor and the trade has accepted it without any returns. After six months' curing, a clean, mild characteristic, aged cheddar flavor usually develops.

The following procedure is recommended:

1. Heat milk, flashing to 160° to 168°F.
2. Cool immediately to 88°F., the setting temperature.
3. Add from 0.5 to 1 per cent clean, active starter.
4. Add 4 to 6 ounces rennet at 0.17 to 0.20 per cent acidity.
5. Coagulation period, 25 to 35 minutes.
6. Cooking temperature 100° to 104°F.
7. Acidity at dipping, 0.145 to 0.155 per cent.

SUMMARY

A maximum flash temperature of 168°F. may be used in heating milk for the manufacture of cheddar cheese. Higher temperatures give a weak texture, a scorched flavor and sometimes allow a bitter flavor to develop.

Heating milk to 160° to 168°F. improves the quality of the cheese in the case of poor milk, although uniform improvement is not noticed in the case of milk of good quality. Gassy milk pasteurized to 176°F. produces cheese of better quality than if the raw milk were used.

Greater uniformity in the cheese is obtained by heating the milk. A yield of 9.49 pounds of cheese for each 100 pounds of milk testing 3.34 per cent butterfat was obtained. The loss of butterfat in the whey was 0.053 per cent lower when the milk was heated.

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EFFECT OF HOMOGENIZING ICE CREAM MIXES BEFORE AND AFTER THE ADDITION OF GELATIN OR SUGAR AND BEFORE AND AFTER CONDENSING*

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It is generally recognized that variations sometimes occur in the properties of ice cream mixes from unknown causes. Observations made from studies at this Station and from commercial practice prompted a study of certain conditions during homogenization which gave some promise of giving information on these problems. The investigation dealt with the influence of adding gelatin or sugar to the mix prior to pasteurization and homogenization as compared with the addition of these ingredients immediately after homogenization. The study also included the effect of homogenization of the mix before and after condensing.

EXPERIMENTAL METHODS

The correct proportioning of the ingredients in the mix was calculated by the method of Price (1). Cream containing 30 per cent of fat, condensed skim-milk, water, 0.5 per cent of a medium grade gelatin and 14 per cent of sugar were the ingredients. The percentages of fat and serum solids in the finished ice cream were 12 and 10, respectively. The cream was separated from the milk of the Station Jersey herd, and the skim-milk was condensed to contain 20 to 25 per cent total solids in large flasks at a temperature of 43°C. under 27 to 28 inches of vacuum.

The ice cream mixes were pasteurized at 62° to 64°C. (143° to 147°F.) for thirty minutes or at 65°C. (149°F.) for twenty minutes. From 50 to 150 pounds of mix were required for one experiment, while for each individual batch not less than 15 pounds were required. The mixes were poured directly into a funnel attached to a Manton-Gaulin homogenizer of 60 gallons per hour capacity.

* Received for publication March 22, 1928.

They were processed at the pasteurization temperature and usually at 2500 pounds pressure. The mixes were cooled in cans placed in cold water and were aged at 3° to 5°C. (37° to 41°F.) for fifteen to twenty hours prior to freezing. The mixes were frozen for uniform periods of time in one gallon experimental freezers which permitted triplicate freezings under identical conditions. The brine temperature was controlled within 0.2°C. and the temperature of the finished ice cream varied half this amount.

The viscosity of the mix was measured with the MacMichael viscometer using the number 22 and 26 wires which had been standardized by oils of known viscosity furnished by the United States Bureau of Standards. The results obtained were expressed as viscosity in centipoises even though plasticity may have influenced the readings. No better means of determining or stating the fluid characteristics of the mixes was available. The temperature of the mix when viscosity determinations were made varied from 3° to 5°C. but was uniform for each series.

The fat globules were measured at a magnification of approximately 2000 diameters using an ocular micrometer disc standardized with the microscope so adjusted that each of the smallest marks represented 0.5 micron. One-half cubic centimeter of the mix to be examined was diluted with 100 cc. of distilled water and mounted as a hanging drop preparation.

The ice cream samples were scored for body, texture, and flavor by A. C. Dahlberg and the author, without knowing their identity. Hardness tests were made after several days aging in the hardening room at −17.8° to −21.1°C. (0° to −10°F.) by the method of Perkins (2). Six tests were made on one brick and the results were calculated to grams required to displace 1 cu. mm. The melting resistance of the ice cream was determined by hourly weighing duplicate pint bricks at room temperature, as previously done by Holdaway and Reynolds (3), and others.

EXPERIMENTAL RESULTS

Effect of homogenizing ice cream mixes with and without gelatin

Gelatin is now usually added to the mix in the dry form prior to homogenization, but in former years it was usually dissolved in water and added to the mix after homogenization. Downey (4) favored the addition of the dry gelatin to the mix before pasteurization, although his results show that the addition of gelatin after homogenization produced slightly harder ice cream of greater melting resistance. Ambrose (5) reported ice cream to

TABLE 1

The effect of homogenizing the ice cream mix with and without gelatin on its viscosity

DATE	DESCRIPTION OF VARIATION IN MIXES		VISCOSITY OF MIXES	
	Per cent gelatin	Homogenization pressure	Homogenized with gelatin	Gelatin added after homogenization
		pounds per square inch	*Cp.*	*Cp.*
January 29	0.3	4,500	1,220	1,570
January 29	0.3	4,500	2,070	3,640
February 20	0.3	4,500	2,260	2,800
March 4	0.5	2,500	1,220	1,220
March 11	0.5	2,500	788	716
April 16	0.5	2,500	694	800
May 21	0.5	2,500	398	426

be smoother in texture and possessed greater melting resistance when the gelatin was added after homogenization.

In this study gelatin was dissolved in water and added before pasteurization and homogenization, and before and after aging. Controls were also prepared without gelatin. In experiments dated January 29 and February 20, 0.3 per cent of high-test gelatin was used but in all other experiments 0.5 per cent of a medium-grade (about 140 grams by the Bloom method) was used. The viscosities of the aged mixes are given in table 1. Although the mixes in each series are quite uniform in viscosity, it is evident that the homogenization of gelatin in the mix results

in a lower viscosity. Gelatin added to the mix just prior to freezing gave reduced viscosities, the extent depending upon the time elapsing between the addition of gelatin to the cold mix and the making of the determination.

A sufficient number of microscopic fields were examined to permit the measurement of 100 individual fat globules and all

TABLE 2

The effect of homogenizing the ice cream mix with and without gelatin on the size and clumping of the fat globules

DATE	AVERAGE SIZE OF FAT GLOBULES IN MICRONS		NUMBER OF CLUMPS FOUND PER 100 INDIVIDUAL GLOBULES		AVERAGE SIZE OF CLUMPS IN MICRONS	
	Before freezing	After freezing	Before freezing	After freezing	Before freezing	After freezing
Homogenized with gelatin						
April 8	1.74	1.47	23	22	4.87 x 3.10	3.27 x 2.50
May 14	1.32	1.35	52	35	4.00 x 2.90	3.00 x 2.20
May 21	1.56	2.05	23	31	8.36 x 5.19	8.22 x 5.48
July 1	1.72	1.84	36	40	4.88 x 2.70	2.75 x 1.95
July 2*	1.72	2.16	36	21	4.88 x 2.70	2.50 x 1.95
Average	1.58	1.77	33.5	29.8	5.52 x 3.47	3.95 x 2.81
Homogenized without gelatin						
April 8	1.32	1.42	20	10	3.15 x 2.00	2.45 x 1.70
May 14	1.21	1.52	31	29	2.80 x 1.90	2.30 x 1.78
May 21	1.89	1.95	25	17	6.74 x 4.10	6.70 x 4.60
July 1	1.65	1.74	32	21	4.50 x 2.70	3.14 x 2.12
July 2*	1.65	1.87	32	21	4.50 x 2.70	2.73 x 1.88
Average	1.51	1.70	27.0	24.5	4.29 x 2.67	3.46 x 2.41

observed clusters were counted and measured. In this manner the relative number of individuals and clusters was obtained. The size of the clumps was obtained by averaging together all the largest dimensions and then all the small dimensions. The data, presented in table 2, show that the presence of gelatin during homogenization tended to increase the size of the fat clumps to a

slight extent. The size of the clusters of fat globules was reduced when the mixes were frozen, but this effect was not uniform for mixes homogenized with or without gelatin.

The addition of gelatin prior to or immediately following homogenization did not alter those properties of the mix which affect its freezing and whipping characteristics. So far as could be observed or determined the mixes handled similarly in the

TABLE 3

The effect of the time gelatin is added to the mix on the melting resistance of the ice cream

DATE	LOSS IN WEIGHT											
	Homogenized with gelatin			Gelatin added immediately after homogenization			Gelatin added just before freezing			No gelatin added		
	First hour	Second hour	Total	First hour	Second hour	Total	First hour	Second hour	Total	First hour	Second hour	Total
	grams	*grams*	*grams*	*grams*	*grams*	*grams*	*grams*	*grams*	*grams*	*grams*	*grams*	*grams*
January 15.....	0.0	74.5	74.5	10.2	74.3	84.5	26.15	105.7	131.8			
January 29.....	50.9	119.1	170.0	41.2	140.0	181.2	62.3	134.6	196.9			
February 20.....	41.0	122.5	163.5	32.0	141.7	171.7	60.9	137.0	197.9	82.0	124.8	206.8
March 4...	51.6	69.0	120.6	46.2	99.9	146.1	61.7	93.0	155.7	84.0	87.7	171.7
March 11..	41.9	69.5	111.4	28.2	82.5	110.7	68.6	91.0	159.6	86.4	78.5	164.9
March 18..	21.7	86.0	107.7	14.8	91.0	105.8	32.6	106.3	138.9	68.4	89.3	157.7
April 16...	61.7	105.7	166.8	61.0	102.1	163.1	85.2	100.5	185.7	103.4	62.4	165.8
May 12....	54.9	117.6	172.5	67.6	115.7	183.3	112.4	104.6	217.0			
May 21....	25.9	120.0	145.9	35.2	130.3	165.5						
Average.	38.8	98.2	136.9	37.3	108.6	145.7	63.7	109.0	172.9	84.8	88.5	173.3

freezers and gave the same overrun under uniform conditions. It seemed unnecessary to present these data.

The ice cream made from the mix to which the gelatin was added immediately after homogenization was placed first for texture in seven out of nine trials and was never placed third or fourth. The ice cream made from the mix homogenized with gelatin was placed first once and was second and third in a total of

eight trials. The evidence indicates that the action of gelatin is slightly stronger when added immediately after homogenization, but this difference is not pronounced and may not be sufficient to be a factor to consider commercially. It is interesting to note that ice cream to which the gelatin was added just prior to freezing was usually scored third, thus demonstrating the importance of aging gelatin in the ice cream mix. The ice cream containing no gelatin was always placed fourth not only because of coarse texture, but also because the body was crumbly and unfrozen syrup often drained from it during storage.

TABLE 4

The effect of the time gelatin is added to the mix on the hardness of the ice cream

DATE	HARDNESS IN GRAMS TO DISPLACE 1 CU. MM.			
	Homogenized with gelatin	Gelatin added immediately after homogenization	Gelatin added just before freezing	No gelatin added
January 15	5.00	5.00	8.00	
January 29	2.40	3.00	3.00	
March 4	9.16	8.80	11.00	9.00 bottom (4.30 top)
March 11	7.50	10.00	10.00	8.00 bottom (3.40 top)
March 18	6.00	6.60	6.00	
April 16	1.66	2.00	2.00	1.35
May 12	3.14	3.38	3.14	

The data, presented in table 3, give the rate of melting of the ice cream at room temperature. The addition of gelatin prior to homogenization as compared with adding gelatin immediately following homogenization had no effect upon resistance to melting, but it can be readily seen that ice cream without gelatin or to which gelatin was added just before freezing melted more rapidly, especially during the first hour.

The results of the determinations of the hardness of the ice cream at $-17.8°$ to $-21.1°$C. given in table 4 show much discrepancy from batch to batch caused by variations in the overrun,

etc. The overruns and other conditions being similar for each freezing within a series permit comparisons within each batch. It can be seen that the hardness was not affected by the time of adding gelatin and that it was greatly influenced by the movement of syrup in the ice cream containing no gelatin, as shown by tests made on the upper and lower sides of the brick.

Effect of homogenizing ice cream mixes with and without sugar

In recent years the general practice has been to add sugar to the mix prior to homogenization, probably to insure pasteurization

TABLE 5

The effect of homogenizing the ice cream mix with and without sugar on viscosity

DATE	HOMOGENIZED WITHOUT SUGAR		HOMOGENIZED WITH SUGAR	
	Single-stage valve	Two-stage valve	Single-stage valve	Two-stage valve
	Cp.	*Cp.*	*Cp.*	*Cp.*
April 8	328		464	
April 16	694		764	
May 21	400		554	
July 2	666		953	
September 25	2,800	2,190	3,600	1,800
October 9	2,720	870	5,360	4,900
October 16	1,570	990	2,080	1,300
October 30	1,530	620	4,480	2,880

of the sugar and to facilitate its complete solution. Numerous experiments were conducted, similar to those just given for gelatin, to determine the effects on the mix and the finished ice cream of adding sugar prior to and following homogenization. Since high viscosities developed under certain conditions the two-stage valve was also used on the homogenizer in some trials to learn how much it altered the results of the tests. Some of the mixes were frozen at a commercial plant to permit comparison of results with those secured in the experimental freezers.

The data given in table 5 show that homogenization of mixes with sugar always produced greater viscosities than when the

sugar was added at a later time. The tests with the two-stage valve gave mixes of lower viscosity, but again the presence of sugar during homogenization increased the viscosity. Numerous other experiments were made which gave the same results, the difference in viscosities being great enough to be easily observed.

In table 6 are data showing the overrun obtained on these mixes. Very low overruns were usually obtained with the experimental freezers on the viscous mixes which had been homogenized with sugar. The overrun was increased by the use of the two-stage valve, but the easier whipping of mixes homogenized

TABLE 6

The effect of homogenizing the ice cream mix with and without sugar on the per cent of overrun obtained

DATE	HOMOGENIZED WITHOUT SUGAR		HOMOGENIZED WITH SUGAR	
	Single-stage valve	Two-stage valve	Single-stage valve	Two-stage valve
	per cent	*per cent*	*per cent*	*per cent*
April 8	87.0		48.0	
April 16	89.0		63.0	
July 2	90.2		61.6	
May 21	93.0		54.2	
September 25	76.4	97.0	61.2	81.5
October 9	71.1	98.3	44.1	69.4
October 16	89.8	92.8	67.3	97.0
October 30	64.2	91.7	38.3	67.9

without sugar was still evident. On account of the impossibility of securing proper overrun in the experimental freezers without drawing the ice cream at too warm a temperature, some of the mixes were frozen at a commercial plant. It was found that in most cases an overrun approximating 90 per cent could be obtained, but the amount of whipping required after the brine had been turned off was variable. Thus the mixes homogenized without sugar whipped to the desired overrun in two minutes less time than when sugar was present during homogenization. A complete mix homogenized with the two-stage valve whipped in two minutes less time than the same mix homogenized with

TABLE 7

The effect of homogenizing the ice cream mix with and without sugar on the size and clumping of the fat globules

DATE	HOMOGENIZED WITHOUT SUGAR			HOMOGENIZED WITH SUGAR		
	Average size of fat globules in microns	Number of clumps found per 100 individual globules	Average size of clumps in microns	Average size of fat globules in microns	Number of clumps found per 100 individual globules	Average size of clumps in microns
Single-stage valve before freezing						
April 8	1.74	23	4.87 x 3.10	2.60	56	7.40 x 5.25
April 16	1.32	52	4.00 x 2.90	1.77	92	6.70 x 4.90
May 21	1.56	23	8.36 x 5.19	1.75	43	10.19 x 6.62
July 2	1.72	36	4.88 x 2.70	2.04	55	6.90 x 4.12
September 25	1.35	92	7.90 x 5.00	1.75	77	8.80 x 5.10
October 9	2.00	61	6.90 x 3.55	1.64	137	9.50 x 6.20
October 16	1.41	98	5.40 x 2.88	1.45	150	6.80 x 3.74
October 30	1.30	131	4.84 x 2.80	1.75	132	7.50 x 4.84
Average	1.55	64.5	5.89 x 3.51	1.84	92.5	7.97 x 5.09
Single-stage valve after freezing						
April 8	1.47	22	3.27 x 2.5	2.58	69	4.45 x 3.15
April 16	1.35	35	3.00 x 2.2	1.40	95	3.23 x 3.20
May 21	2.05	31	8.22 x 5.48	1.77	79	5.60 x 3.65
July 2	1.84	40	2.75 x 1.95	1.54	53	4.14 x 3.00
Average	1.67	32	4.31 x 3.03	1.82	74	4.35 x 3.25
Two-stage valve before freezing						
September 25	1.34	64	5.90 x 3.70	1.50	58	5.75 x 3.34
September 30	1.43	138	4.50 x 2.57	1.43	66	5.25 x 3.30
October 9	1.05	80	3.50 x 2.20	1.30	113	6.65 x 3.67
October 16	1.08	52	2.49 x 1.55	1.15	117	3.47 x 2.12
October 30	1.00	67	2.55 x 1.60	1.15	157	4.65 x 2.90
Average	1.18	80	3.78 x 2.32	1.30	102	5.15 x 3.06

the single-stage valve. Several dozen tests not reported in the table confirm the result that the mixes of high viscosity produced by the presence of sugar during homogenization were hard to whip.

An extensive study was made of the size of the fat globules and of the number and size of fat globule clusters in the mixes homogenized with and without sugar for the purpose of determining any relationships that might exist between the dispersion of the fat and the viscosity and whipping properties of the mix. A small portion of the data secured has been presented in table 7 which permits direct comparisons with the data on overrun and viscosity given in tables 5 and 6. The size of the individual fat globules was not affected by the presence of sugar during homogenization or by freezing the ice cream. The number of fat clusters and their size was increased by adding sugar prior to homogenization and their size was reduced by the freezing process. The two-stage valve produced slightly smaller individual globules and clumps than the single-stage valve. It is evident, therefore, that in a general way an increase in the size of fat clusters was associated with increased viscosity and difficult whipping, although it should be observed that the comparison should be made for the same mix homogenized with and without sugar. These results are in agreement with those of Mortensen (6) on the influence of homogenization on fat clumping and viscosity, and those of Martin and Dahle (7) on the influence of the two-stage valve on fat clumping, viscosity, and whipping.

The extensive data secured were too bulky to present in full. Measurement of 1235 individual globules of homogenized mixes without sugar with the single-stage valve gave an average size of 1.55 microns as compared with a size of 1.72 microns obtained for 1327 measurements of fat globules in the mix homogenized with sugar. The size of the fat clusters increased 1.69 x 1.11 microns when the mix was homogenized with sugar when compared with the mix homogenized without sugar, as shown by a total of 2056 measurements. The size of the fat clusters was reduced about 40 per cent due to freezing the mix, according to the average of 3405 measurements. The decrease in the size of fat clusters due to the

use of the two-stage valve approximated 30 per cent as shown by 983 measurements. The reduction in size of fat clusters due to freezing and the use of the two-stage valve was slightly greater when the mix contained sugar during homogenization.

The ice cream was judged by two judges in all of the experiments, comparing the homogenization of the mixes with and without sugar and with both the single-stage and two-stage valve. The texture and quality of the ice cream was not affected greatly by the addition of sugar to the mix before or after homogenization. The ice cream frozen from the mixes homogenized without sugar

TABLE 8

The effect of homogenizing the mix with and without sugar on the hardness of the ice cream

DATE	HOMOGENIZED WITHOUT SUGAR		HOMOGENIZED WITH SUGAR	
	Overrun	Grams to displace 1 cu. mm.	Overrun	Grams to displace 1 cu. mm.
	per cent		*per cent*	
August 20	90.0	1.20	90.0	1.33
September 3	95.0	1.60	88.0	1.77
October 2	70.3	3.38	74.4	4.00
October 16	92.8	2.17	97.0	2.17

was in most cases slightly smoother in texture than the ice cream frozen from the mixes homogenized with sugar.

Although considerable data were obtained upon the hardness and rate of melting of ice cream as influenced by the presence of sugar during homogenization and the use of the two-stage valve, they are not presented because of the difficulty in securing uniformity in the freezing process, particularly overrun. It is possible to select four batches reported in table 8 in which comparable yields were secured and which show uniform hardness and rate of melting, even though the treatment of the mixes varied as stated.

INFLUENCE OF HOMOGENIZATION OF THE MIXES BEFORE AND AFTER CONDENSING

The fact that the mixes with less clumping and smaller sized clumps whipped easier and that the texture of the ice cream was improved made it desirable to endeavor to homogenize the ice cream mix in such a way, if possible, that there would be fewer and smaller clumps.

When milk which contained from 5 to 10 per cent of fat was homogenized, very little clumping of the fat globules was noticeable. These results furnished a clue for a method of preparing and homogenizing ice cream mixes to decrease the number and size of the fat globule clumps. Mojonnier and Troy (8) and Peterson and Tracy (9) recommended condensing the ice cream mix before homogenization.

Milk standardized to contain 10 per cent of fat was pasteurized and homogenized and sufficient water was removed from this mix by evaporation in partial vacuum so that when sugar, gelatin, and water were added it would contain the right proportion of ingredients. The size of the fat globule clumps in the mixes prepared in this way were greatly reduced and the average size of the fat clumps in the mixes after freezing were unusually small. There were a number of large individual fat globules with a few very small globules attached to them, apparently caused by fusion of some fat globules during condensing. These mixes whipped very readily. A mix prepared in this way frozen in a factory freezer was drawn from the freezer in seven minutes at a temperature of −3.4°C. (25.8°F.) with an overrun of 94 per cent. This ice cream was of very good quality.

In the next five experiments half of the mix was homogenized and then condensed, while the other half of the mix was condensed first and then homogenized. In these experiments the mixes which were homogenized before condensing whipped very readily, to an average overrun of 95.5 per cent, but the mixes which were condensed and then homogenized whipped to an average overrun of only 56 per cent. The addition of sugar to the 10 per cent milk homogenized before condensing did not make the resulting mix difficult to whip.

The ice cream frozen from the mixes homogenized before condensing was judged in comparison with the ice cream frozen from the mixes homogenized after condensing. The ice cream resulting from the first procedure was placed first in every case. The texture of this ice cream was somewhat better. Likewise its body was usually more creamy.

SUMMARY

The qualities of ice cream or the characteristics of the mix were altered but slightly by adding gelatin before or after homogenization. The fat clumps may have been larger when gelatin was added before homogenization, although the difference, if any, was small. The viscosity of the mix was slightly increased by adding the gelatin immediately after homogenization, but the whipping properties of the mix were not affected.

The texture of the ice cream was very slightly, yet noticeably, improved when the gelatin was added immediately after homogenization. Neither the melting resistance nor the hardness of ice cream varied with the time of adding the gelatin.

The data on the increased viscosity of the mix and on the improved texture of ice cream due to adding the gelatin after homogenization warrant the conclusion that the action of gelatin is slightly greater when added at this time. It is doubtful, however, that this difference is enough to be of commercial importance to the ice cream manufacturer.

The addition of sugar prior to homogenization greatly increased the extent of fat clumping, the viscosity of the mix, and the difficulty of securing the desired overrun.

The quality and properties of ice cream were not materially affected by the addition of sugar before or after homogenization, although in most cases the ice cream made from the mix homogenized without sugar was slightly smoother and more creamy.

The two-stage valve reduced the size of fat clusters, the viscosity of the mix, and permitted an easier incorporation of air.

The freezing process reduced the size of the fat clusters, but the reduction was not uniform for all mixes.

The mix homogenized before condensing contained smaller fat globule clumps, was easier to whip, and produced an ice cream slightly better in texture and quality than a similar mix homogenized after condensing.

The author wishes to express his appreciation to the Geneva Division of the General Ice Cream Company for the privilege of freezing some of the mixes at the Geneva plant.

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THE EFFECT OF HYDROGEN ION CONCENTRATION ON THE BACTERIAL CONTENT OF GELATIN*

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INTRODUCTION

The consuming public is becoming increasingly exacting in its demand for ice cream of high sanitary quality. The modern ice cream maker not only prides himself in the scrupulous care used in the handling of the mix in his plant, but he is also very fastidious in the selection only of raw products which are above reproach from the sanitary point of view. To this end the bacterial count has been employed as an index to the care used in the production and handling of the various ingredients of the ice cream mix. In many ice cream plants the sanitary quality of the gelatin is judged on a basis of the number of bacteria it contains. The tendency to associate high bacterial counts with insanitary conditions of manufacture and handling of gelatin comes largely through analogy with the bacterial analysis of dairy products.

The gelatin industry has made a tremendous improvement in the sanitary control of its manufacturing process during the past few years. It would be difficult to find an example of an industry that has done as much in as short a time toward the improvement of the sanitary quality of its product as has been accomplished in the past four or five years by the gelatin manufacturers. The recent article by Fay and Olson (1) published in 1927 was based on samples of gelatin collected in 1924. In this report the bacterial counts ranged from less than ten to 108,000,000 per gram of dry gelatin. Over half of the 50 samples analyzed contained in excess of 1,500,000 per gram. Bacterial analyses on samples collected after 1924 show that it is quite rare to find gelatin with such excessive numbers of bacteria.

* Received for publication April 7, 1928. Contribution No. 101 from the Department of Bacteriology, Kansas Argricultual Experiment Station, Manhattan, Kansas.

The question has been raised as to whether or not the bacterial count as applied to gelatin offers a satisfactory index to the sanitary quality of the product. It is ordinarily assumed that gelatin made and handled under carefully controlled conditions will have relatively few bacteria in it. On the other hand, gelatin which has been less carefully controlled may have a correspondingly larger number of bacteria. If a bacterial count has any value as one of the criteria of quality in gelatin it would be on the basis of the assumptions mentioned.

One difficulty that is frequently encountered when bacterial numbers are used as an index to quality, is the tendency to misinterpret the significance of the results of the analysis. The misinterpretation of bacterial counts is traceable in many instances to an attempt to use the results as an index to the safety of the product. The interpretative value of any bacterial count lies chiefly in its use as an index to laxity in sanitary control methods. If experience proves that it is feasible and practical to produce gelatin with less than a given number of bacteria per gram, a gelatin manufacturer who cannot meet this requirement, evidently is not exercising as much care in manufacturing and handling the product as he should. The extra 5000 or 100,000 bacteria in his gelatin may be, and in most cases are, perfectly harmless. The bacteria in themselves are of secondary importance; it is rather the conditions which their presence reveals that is of serious concern. It is only to the degree that laxity of control may pave the way for the entrance of pathogenic bacteria that the bacterial count has a connection with the safety of the product. The extent to which the laxity of control is a predisposing factor to contamination with pathogenic bacteria could be determined only by inspection.

In the manufacture of gelatin the practice is sometimes followed of adjusting the reaction to a rather high acidity (low pH) during the manufacturing operations. The pH may or may not be again adjusted to near the neutral point. Recently it has been claimed that the acidity of many gelatins is so high that bacterial development is inhibited. Sommer (2), Turnbow and Milner (3) and also Dahlberg (4) have shown that the value of

the keeping quality test is greatly diminished by the fact that the growth of liquefying bacteria, even though present in gelatin, may be inhibited by the high acidity of the product.

The question then arises as to whether the high acidity might not also render the bacterial count of doubtful value as a means of judging the sanitary quality of gelatin.

EXPERIMENTAL

With these points in mind the following experiment was designed to study the effect of the hydrogen ion concentration on the growth of microörganisms in gelatin. The 34 samples of gelatin used in the experiment were collected during the summer of 1927 from various American producers and distributors.

A 10 per cent solution of each of the samples of gelatin was prepared aseptically and 10 cc. placed in each of four sterile test tubes. Five drops of a 0.04 per cent aqueous solution of brom-thymol blue were added to each tube. The four tubes were divided into two pairs and labelled A and B, and X and Y. The X and Y tubes were each inoculated with 0.1 cc. of a mixed microbial suspension, in order to be certain that organisms were present. Preliminary plating of these gelatins showed that some were almost sterile, so that it was necessary to have a pair of tubes artificially contaminated. The organisms used for inoculating were obtained from an agar plate which had been exposed to the air and then incubated twenty-four hours. It was estimated that the 0.1 cc. inoculum introduced approximately 150,000 organisms, including yeasts, molds, spore-bearing and non spore-bearing bacteria.

Tubes A and B were not inoculated, and any subsequent microbial development was dependent upon the original flora of the gelatin.

In one tube of each pair, tubes B and Y, the reaction was adjusted to pH 7.0, and in the remaining tube of each pair, tubes A and X, the reaction of the original gelatin was not altered. Adjustment of the reaction to pH 7.0 was accomplished by admitting sterile NaOH until the brom-thymol-blue approached a grass-green color.

The set of four tubes, therefore, consisted of two uninoculated and two inoculated tubes of gelatin, one tube of each pair having the reaction of the original gelatin unaltered, and the remaining tube of each pair with the reaction adjusted to pH 7.0.

The aim of this experiment was to determine the effect of the hydrogen ion concentration of the gelatin on the growth of microörganisms. If no growth developed in tube A (the original gelatin) it might have been the result of one or more of the following factors; sterility, reaction, or the presence of antiseptic substances. The inoculated tubes, X and Y, would serve as controls on sterility. If failure of growth in tube A were due to the second factor, viz., the reaction, tubes B and Y with a neutral reaction would serve as checks. If lack of growth in tube A were due to the combined effect of the two factors, sterility and reaction, tube Y would be the only one in the series in which growth would obtain. If an antiseptic or disinfectant substance had been added, there would probably be no growth in any of the tubes.

All tubes were incubated twenty-one days at 37°C., and the number of days required for growth to become evident was recorded. No growth after twenty-one days was regarded as negative. All samples showing no growth after twenty-one days were examined microscopically, and subcultures were made by transferring 0.1 cc. of the gelatin from the incubated tube to sterile broth. If the failure of growth in the gelatin were due to antiseptic action, removal of organisms that were still viable would likely result in their development in the broth subculture.

In table 1 are shown the bacterial count per gram of dry gelatin, the pH, the keeping quality in days at room temperature, the price per pound, and the time required for growth to appear in the four tubes treated in accordance with the previous description.

The pH values were determined by the colorimetric method of Medalia (5) and the plate counts were made in accordance with the Standard Methods of the American Public Health Association.

Referring to the data in columns A, B, X and Y in table 1, it

TABLE 1

The results of bacterial count, reaction and keeping quality studies with 34 samples of gelatin

SAMPLE NUMBER	BACTERIAL COUNT PER GRAM	pH	KEEPING QUALITY		GROWTH				GROWTH IN SUBCULTURES FROM NEGATIVE TUBES	PRICE PER POUND
					In uninoculated tubes		In inoculated tubes			
			Colonies appeared	Surface liquefaction	A	B	X	Y		
					pH unaltered	pH adjusted to 7.0	pH unaltered	pH adjusted to 7.0		
			days	days	days	days	days	days		cents
16	900	4.8	3	—	7	2	5	2		50
15	40	4.9	—*	—	6	4	5	2		55
17	100	4.9	3	—	7	3	5	1		45
18	4,500	5.1	4	20	13	2	11	1		40
23	1,200	5.3	9	17	—	2	9	2	+	40
22	900	5.5	3	—	10	2	10	1		35
9	12,000	5.6	7	13	13	3	5	1		27.5
19	25	5.7	3	20	5	2	2	1		43
25	200	5.7	9	18	—	5	5	1	+	35
7	250	5.7	6	10	2	2	2	1		55
20	2,500	5.7	4	—	4	2	2	1		50
6	Less than 5	5.8	21	—	—	5	5	2	+	55
8	10	5.8	7	18	10	4	5	2		45
21	800	5.8	3	13	4	2	1	1		40
33	5	5.9	—	—	—	6	5	5	—	45
12	60	5.9	3	7	2	2	2	1		25
34	30	6.2	13	17	—	—	2	2	++	50
2	5	6.3	3	7	5	2	1	1		44
10	5	6.3	7	—	10	10	1	2		54
32	10	6.3	—	—	—	7	5	7	—	40
24	Less than 5	6.4	6	10	5	4	2	1		55
14	10	6.4	10	18	9	9	1	2		38
4	Less than 5	6.5	4	9	2	3	1	1		57
5	Less than 5	6.5	—	—	16	5	1	1		50
13	10	6.5	10	21	13	4	2	2		45
11	20	6.5	4	7	6	5	1	1		34
1	4,900	6.5	4	9	3	3	1	1		32
28	9,500	6.5	6	9	7	4	1	1		39
3	15,000	6.5	3	—	2	2	1	1		39
27	20,000	6.5	1	2	1	2	1	1		30
26	80	6.6	9	13	5	5	1	1		45
30	170	6.6	7	—	—	6	5	6	—	51
31	80	6.6	6	20	7	—	2	5	—	56
29	1,100	6.6	—	—	—	6	21	5	—	44

* The minus sign (—) indicates no growth in 21 days incubation.

will be noted that organisms failed to develop in one or more of the tubes prepared from samples 23, 25, 6, 29, 30, 31, 32, 33, and 34. Samples 29, 30, and 31 were obtained from the same company, 32, 33, and 34 were from another company, and each of the others, 6, 23, and 25 were from separate manufacturers.

Sample 23 showed no growth in tube A in twenty-one days, but when the reaction was adjusted to the neutral point, as in tube B, growth was evident in two days. The subculture made from tube A after twenty-one days revealed the presence of living organisms and that microbial growth in the original gelatin had been inhibited. Heavy inoculation of this gelatin, as in tube X, resulted in growth after nine days in spite of the reaction. It is evident that in this sample of gelatin, the reaction has been a determining factor in keeping down bacterial development. What has been said about sample 23 applies equally well to samples 25 and 6.

In the case of samples 30, 32, and 33, bacterial growth not only failed to develop in the original gelatin (tube A) in twenty-one days, but there was also no growth in subcultures made from these tubes. Sample 34 showed no growth in tubes A and B, but growth was obtained in the subcultures. Considering the low bacterial counts of these gelatins, it seems logical to attribute the sterility of tubes A and B to the absence of organisms capable of developing in a gelatin medium. In sample 31 the failure of growth in tube B (pH 7.0) is probably the result of the presence only of acidophilic types.

The results obtained with sample 29 are not so easy to explain. It will be noted that tube A showed no growth after twenty-one days and also no growth in the subculture. The mixed culture of organisms inoculated into tube X, however, failed to show any evidence of growth until the twenty-first day of incubation. When the reaction was adjusted to pH 7.0, growth occurred in less than one week. One might assume that the reaction was the inhibitory agent, until it is noted that the reaction of the original gelatin was almost neutral (pH 6.6). The probability that there was a disinfectant present is virtually eliminated by the readiness with which growth appeared in tubes B and Y.

The bacterial count showed 1100 per gram for this gelatin, which would not justify attributing the lack of growth in tube A to the relative sterility. It seems evident that the factor which prevented bacterial development was effective in a slightly acid medium, but less effective in a neutral gelatin. Repetition of the work with this sample has given essentially the same results.

The results of these experiments indicate that although the acidity of many of the gelatins studied had a retarding effect on the growth of bacteria, it did not entirely prevent their development. The adjustment of the reaction to pH 7.0 hastened growth in 21 of the 34 gelatins, especially in those with a high acidity.

The effect of neutralizing the gelatin is particularly noticeable in the results obtained with the inoculated tubes X and Y. With but three exceptions (7, 20, and 21) an original reaction more acid than pH 5.9 in tube X required more than twice as long for growth to become evident, than was required in tube Y having a neutral reaction. In table 1 it may also be observed that in only one of the samples (no. 29), having a reaction less acid than pH 5.9, did neutralization of the gelatin in tube Y produce any marked effect on the rate of microbial development. However, several of the samples more nearly neutral than pH 5.9 showed more rapid development of organisms in tube B than in tube A. Failure for growth to develop in several of the A and B tubes was very likely due to the fact that there were very few organisms present.

It is a well established fact that many microörganisms are more easily killed in a high acid medium than in one that is neutral in reaction. The practice of manufacturing gelatin with the reaction at a low pH takes advantage of this fact and results in more effective bacterial destruction. Furthermore, during the drying process there is much less likelihood of bacterial growth taking place if the reaction is very acid. When gelatin is placed in the drying tunnels, heavy contamination from the air may result, unless special precautions are taken to purify the air. The results of this experiment indicate that very little growth would take place during the drying process if the gelatin had a

low pH, whereas growth would not be inhibited if the reaction were near the neutral point. The sanitary conditions being equal, one would expect a gelatin which had been processed with a high acidity to contain fewer bacteria than one processed with the reaction near the neutral point. In other words, the reaction at which a gelatin has been processed should be taken into consideration when the bacterial count is used as an index to the sanitary conditions surrounding the production of the gelatin.

On the other hand, one would not necessarily expect a correlation between the reaction and the bacterial count. In view of the fact that some manufacturers readjust the reaction of their gelatin to near the neutral point, the pH of the finished product may not reveal the reaction at which it was processed. A survey of the bacterial counts and the pH values given in table 1 at once

TABLE 2

The distribution of pH values of 34 samples of gelatin

	pH				
	4.8–5.0	5.1–5.5	5.6–6.0	6.1–6.5	6.6
Per cent of samples.....	8.8	8.8	29.4	41.2	11.8

shows this lack of correlation. Tracy and his coworkers (6) in reporting a study of 48 samples of gelatin, state that most of the samples with a low pH also had a low bacterial count. The reactions of the samples analyzed by them ranged from pH 4.05 to 7.35.

The reaction of most of the samples was between pH 5.5 and 6.5. Table 2 shows a distribution of the samples based on the reaction. There were 8.8 per cent of the samples with a reaction between pH 4.8 and 5.0; 8.8 per cent between pH 5.1 and 5.5; 29.4 per cent between pH 5.6 and 6.0; 41.2 per cent between pH 6.1 and 6.5; and 11.8 per cent with a reaction of pH 6.6.

KEEPING QUALITY TEST

The results of the keeping quality test are recorded in table 1 under two headings; the days required for the appearance of

colonies, and for the first evidence of surface liquefaction of the gelatin. It will be noted that 5 of the 34 samples (14.7 per cent) showed no colony development after twenty-one days at room temperature, and 13 samples (38.2 per cent) did not show any liquefaction after the same period of incubation. There were 9 other samples which required more than two weeks for liquefaction to appear. That liquefaction is not necessarily associated with high bacterial counts may be seen by noting the results with samples 19, 8, 12, 34, 2, 24, 14, 4, 13, 11, 26, and 31, each of which showed liquefaction in from one to three weeks, even though the bacterial count did not exceed 80 per gram in

TABLE 3

The increase in the per cent of samples of gelatin having a low bacterial content, based on samples collected in 1924 and 1927

PLATE COUNT PER GRAM OF GELATIN	34 SAMPLES COLLECTED 1927	50 SAMPLES COLLECTED 1924
	per cent	*per cent*
Sterile (1 to 5 dilution)	12	0
10 or less	32	2
100 or less	56	4
1000 or less	73	14
5000 or less	88	20
10,000 or less	91	22
20,000 or less	100	30

any case. Two of these samples (nos. 24 and 4) liquefied on the surface in ten and nine days respectively, although the bacterial analysis in each case resulted in sterile plates in 1 to 5 dilutions. Molds were responsible for liquefaction of most of the samples. It would seem logical from the experience with these gelatins that a mold count would check more closely with the liquefaction test than a bacterial count.

IMPROVEMENT IN SANITARY QUALITY OF GELATIN

At various places in the literature statements are made to the effect that the bacterial content of gelatin now on the market is very much lower than it was a few years ago. Evidence to support this idea is afforded in the results in table 3. The bac-

terial counts of 50 samples of gelatin collected in 1924 by Fay and Olson (1) are compared with the bacterial counts of the samples reported in this paper. Table 3 shows a comparison of the percentage of samples having less than a given number of bacteria per gram in the groups of gelatins collected in 1924 and 1927 respectively. It may be noted, for example, that only 4 per cent of the samples collected in 1924 contained less than 100 bacteria per gram, whereas in 1927, 56 per cent contained less than this number. Similarly, in 1924 only 30 per cent of the gelatins studied contained 20,000 or less bacteria per gram, and in 1927 none of the samples exceeded this figure. It is believed that the samples are sufficiently representative of the gelatins now in use in ice cream plants of this country to justify the assertion that the bacterial content of gelatin now available to the ice cream industry has been greatly reduced from what it was a few years go.

SUMMARY

A study of 34 samples of gelatin failed to reveal any relation between the reaction and the bacterial count. The bacterial counts ranged from less than 5 bacteria per gram to 20,000, and the reactions expressed as pH were between 4.8 and 6.6. The keeping quality test failed to check with the relative bacterial counts since some of the samples with the highest counts failed to liquefy in twenty-one days at room temperature, and some of the apparently sterile samples developed liquefaction in as short a time as nine days.

A study of the effect of the reaction on bacterial growth revealed that the high acidity of some of the samples had a marked deterring action on the rate of growth of the microörganisms. Although the high acidity of some of the gelatins exerted a marked retarding effect on the development of microörganisms, in no case did the reaction completely inhibit growth where a mixed microörganic population was added.

Under practical conditions, gelatin produced in an insanitary plant where no effort is made to prevent contamination, especially during the drying process, the resulting contamination would

likely be composed of a wide variety of microörganisms, comparable perhaps to the heterogeneous mixture used in artificially contaminating the gelatins in this experiment. The results obtained indicate that if such contamination were to take place while the gelatin was in the drying alleys, very little growth would be likely to result in those gelatins having a high acidity. In other words, the resulting microbial numbers would approximate the extent of contamination since little or no growth would have taken place. On the other hand, if a gelatin with a nearly neutral reaction were subjected to the same contamination, growth of the organisms during the drying process would likely result. A numerical estimate of the microörganisms in this instance would lead to a misinterpretation of the relative sanitary conditions under which the two gelatins were produced.

Undoubtedly many of the organisms present in the finished product die before the gelatin reaches the consumer as a result of the unfavorable environmental conditions, of which high acidity is only one. In other words, the bacterial analysis, under any conditions, is likely to present a picture of the conditions surrounding production of the gelatin which has been modified by the effect of environmental factors on the microbial flora of the finished product. Even though some of the more sensitive organisms originally present in gelatin may have been destroyed, and the growth of other microörganisms deterred by adjustment of the pH, it is believed that gelatin which has been carelessly produced will have a relatively high bacterial count. However, intelligent interpretation of any bacterial count, whether it be on gelatin or any other product, depends on a thorough understanding of, and adequate allowances for, all the factors which may tend to increase or decrease the number of bacteria. The results of this investigation indicate that in interpreting a low bacterial count of gelatin, one of the factors to be taken into consideration is the reaction. This, however, does not render the bacterial count of gelatin useless. The purchaser of gelatin can eliminate from consideration many samples of gelatin because of the undesirable conditions which their high bacterial counts reveal. He cannot, however, be absolutely certain that gelatin

with a low bacterial count is *per se* beyond reproach from the standpoint of sanitary quality. This interpretation never should be made on the basis of a bacterial analysis of any product. A bacterial count on gelatin or any other product only indicates a conclusion and never proves it, unless that conclusion is corroborated by an inspection of the source of supply. A low bacterial count indicates that at least an effort has been made on the part of the manufacturer to prevent excessive contamination of his product and to destroy those bacteria which do gain entrance. If the acidity is high, it is likely that the low bacterial count may be due in part to the death of organisms incapable of surviving the environment, and to the increased efficiency of bacterial destruction by heat in high acid media. Nevertheless, if gelatin has a low bacterial count it indicates, even though it does not prove, that the conditions under which the gelatin was produced did not permit of excessive contamination or else more of the resultant heterogeneous microbial flora would have survived. A low bacterial count is, therefore, believed to be a fairly good index to gelatin of good sanitary quality, although the factors affecting bacterial destruction and growth, such as the acidity, must be taken into consideration.

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A COMPARISON OF THE VOLATILE-SOLVENT METHOD WITH THE VACUUM-OVEN METHOD FOR DETERMINING MOISTURE CONTENT OF CHEESE*

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In the work described in this paper the writer has added improvements to the technique of the volatile solvent (toluene) method, also known as the distillation method, of moisture determination, and has compared this method with the vacuum-oven method at 98° to 100°C., in determinations on a number of varieties of cheese.

The distillation method of moisture determination was first used by Marcusson (1) in 1905, and has since been improved by Rogers (2), Michel (3), Hart (4), Dean and Stark (5), Bidwell and Sterling (6), Normann (7), Gisiger (8), and Jones and McLachlan (11). It has been tentatively adopted for certain organic substances by the Association of Official Agricultural Chemists (9, 10).

This method consists essentially in boiling a weighed sample of cheese with toluene (boiling point, 111.0°C.) or other suitable volatile solvent in a flask connected to a condenser by means of a Bidwell and Sterling (6) distilling tube receiver, and calculating the moisture content by reading, on the graduated portion of the tube, the amount of moisture which has distilled over. The method is fully described by the investigators mentioned above.

A few important details of the method, however, should be mentioned. All moisture adhering to the upper part of the distilling tube is pushed down, after the tube is disconnected, by the use of a rubber policeman described by Rogers (2). The

* Received for publication April 21, 1928.

† Acknowledgment is made to Paul D. Watson of these laboratories for suggesting the use of collodion for coating the corks in making distillation tests and for other valuable suggestions; and to K. J. Matheson, who had charge of the manufacture of the Swiss cheese upon which the determinations were made.

rubber should be small and should be cut to a rather thin and narrow edge. A small copper wire with a loop on the end, described by Hart (4), should be used for brushing free any droplets of water or toluene which adhere to the surface of the smaller part of the tube.

Before being used, each tube is numbered and accurately calibrated by running several check tests on accurately measured quantities of water, as described by Bidwell and Sterling (6). These investigators obtained readings of 1.98 cc. when using 2 cc. of water, thus reading the tube with a correction of +0.02 cc.

Improvements have been added to the technique of the method. The paraffin or glycerine bath in which the flasks are to be boiled, described by Rogers (2), is heated to a temperature of about 140°C. and this temperature is gradually increased to about 150°C. at the completion of the test. Thus the distillation is conducted at the rate of about two drops per second at first, to about three to four drops per second before boiling is stopped; and the flow of distilling liquid is brought to about 1 to 2.5 cm. above the lower end of the cold-water column of the condenser. The use of the bath prevents bumping in most cases and reduces charring of the sample to a minimum.

The corks are soaked in collodion and allowed to dry for at least an hour before being used, in order to prevent leakage or absorption of moisture by the corks.

The tubes are placed in a water bath at room temperature for an hour or longer before reading.

It is obvious that the percentage composition of a weighed sample must be measured in terms of weight rather than of volume. The correction for the density of water (0.012 cc. for 4 cc. at 20°C.) is subtracted from the corrected tube reading.

EXPERIMENTAL

A number of samples of Swiss cheese were boiled for one and one-half hours, the tubes removed, and the readings taken. The boiling was then continued for two hours, new tubes were used, and an average of 0.6 per cent additional liquid was distilled over. This last distillate was treated with $KMnO_4$ and gave a

heavy precipitate of MnO_2, indicating that the last traces of distillate might be largely formic acid (boiling point, 100.47°C.) or rather aldehyde or acid impurities. In fact the distillate from routine tests of cheese at one and one-half hours or longer, when treated with permanganate, fades slowly in color from purple to cherry red, and finally a trace of precipitate settles out. This indicates the presence of impurities and may partially

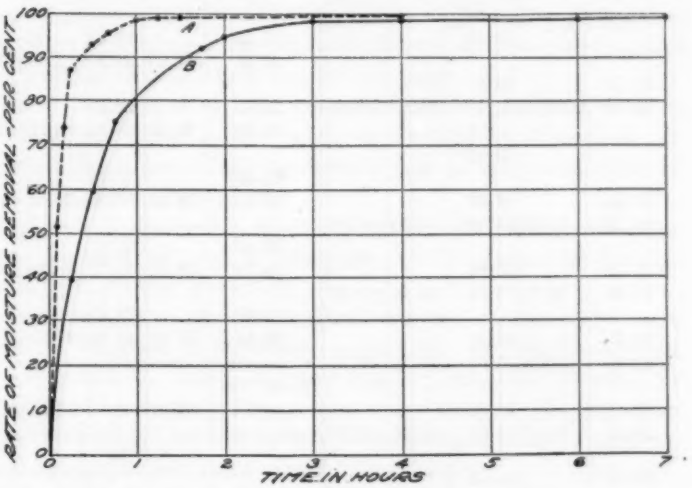

FIG. 1. SHOWING RATE OF REMOVAL OF MOISTURE FROM SWISS CHEESE BY THE TOLUENE-DISTILLATION METHOD AND BY THE VACUUM-OVEN METHOD AT 98° TO 100°C.

A, distillation method; *B*, vacuum-oven method at 98° to 100°C.

account for the fact that the readings obtained by the distillation method are slightly higher than those obtained by the vacuum-oven method.

Four samples of Swiss cheese were run in the vacuum-oven until they ceased to lose weight. The time required was twelve hours. They were then transferred quickly to the toluene flask and boiled for one hour, resulting in 0.78 per cent additional distillate. This liquid showed a trace of impurity by the permanganate test. A

TABLE 1

Comparison of the distillation method and the vacuum-oven method for determining the moisture content of five varieties of cheese

OVEN METHOD		TOLUENE METHOD		DIFFERENCE
Domestic Swiss, cured				
per cent	*per cent (average)*	*per cent*	*per cent (average)*	*per cent*
33.42		34.87		
33.40	33.41	34.69	34.78	+1.37
34.27		34.88		
34.22	34.24	35.20	34.74	+0.50
		34.50 *		
		34.40 *		
33.53		34.37		
33.57	33.55	34.53	34.20	+0.65
		34.00 *		
		33.90 *		
34.35		35.46		
34.30	34.32	35.00	35.23	+0.91
35.56		35.98		
35.35	35.45	36.26	36.12	+0.67
32.32		33.54		
32.36	32.34	32.72	33.13	+0.79
33.44		34.45		
33.51	33.47	34.65	34.55	+1.08
35.16		35.40		
35.11	35.13	35.90	35.65	+0.52
35.09		35.10		
35.04	35.06	35.60	35.35	+0.29
Total average.....	34.11		34.86	+0.75
Brick				
37.01		37.90		
37.14	37.07	38.20	38.05	+0.98
Imported Swiss				
34.37		35.50		
34.82	34.59	35.30	35.60	+1.01
		35.70		
		35.90		

OVEN METHOD		TOLUENE METHOD		DIFFERENCE
Domestic Swiss, green				
per cent	*per cent (average)*	*per cent*	*per cent (average)*	*per cent*
37.54		38.62	38.62	+1.02
37.67	37.60			
36.11		36.90		
35.89	36.00	36.30	36.60	+0.60
37.46		38.55		
37.30	37.38	38.35	38.45	+1.07
35.90		36.60		
35.83	35.86	36.80	36.70	+0.84
36.56		37.72		
36.34	36.45	37.36	37.54	+1.09
36.87		37.82		
36.76	36.81	37.72	37.87	+1.06
36.09		37.17		
36.30	36.19	36.83	37.00	+0.81
Total average....	36.61		37.54	+0.93
Cottage				
77.90		78.40		
77.04	77.47	77.80	78.10	+0.63
Cheddar				
34.63		35.70		
34.65	34.64	36.00	35.86	+1.22
		35.90		
Roquefort				
41.35				
41.23	41.29	41.70	41.70	+0.41
39.27		39.90		
39.13	39.20	39.50	39.70	+0.5
Total average....	40.24		40.70	+0.46

Average of all varieties +0.854

* Determination on a different sample from the same cheese, ten days later, by another investigator.

uniform time of one and one-half hours for boiling was decided upon for the varieties of cheese studied.

All samples of Swiss cheese were taken with a cheese trier. These sample plugs were about 6 inches in length, but only the 3-inch portion nearest the center of the cheese was used. A vacuum of 24 inches and a constant temperature of 98° to 100°C. were maintained in the oven.

Figure 1 shows the results of a detailed study of the rate of removal of moisture from Swiss cheese. Curve B represents a total of 51 weighings taken at irregular intervals, considering the results obtained at ten hours as 100 per cent.

It was found that at least six to seven hours was required to dry the samples to constant weight in the oven and that after ten to twelve hours practically no further loss of weight occurred in ten hours additional boiling.

In Curve A the figures obtained upon the samples boiled for four hours were taken as 100 per cent, and no appreciable distillation was noted after four hours.

A comparison of the two methods on five varieties of cheese shows an increase in moisture content by the volatile-solvent method at one and one-half hours, ranging from 0.46 per cent for Roquefort cheese to 1.22 per cent for Cheddar cheese, when compared with the results obtained by the vacuum-oven method. These figures include the average tube correction, +0.4 per cent, and the deduction for water density, −0.1 to −0.12 per cent.

Closer checks were obtained by the vacuum-oven method than by the distillation method. Both methods produced a pronounced brown color in fresh cheese which still contained lactose, indicating that lactose decomposition was brought about by both methods. (See table 1.)

SUMMARY

Toluene removes moisture rapidly without causing undue charring or decomposition of the material and is recommended as a very satisfactory distilling liquid.

Coating the corks with collodion, correcting for the density of water, and using a paraffin or glycerine bath at 140° to 150°C.,

are improvements which increase the efficiency and accuracy of the distillation method.

This method gives results for cheese which are slightly higher than the results obtained by the vacuum-oven method. It is considered undesirable to boil the material more than one and one-half hours when the rate of boiling is properly regulated.

Closer checks are obtained on duplicate samples by the vacuum-oven method than by the distillation method. The latter method is much more rapid and is very accurate for determinations on cheese.

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BOOK REVIEWS

Fundamentals of Dairy Science. By Associates of Lore A. Rogers. The Chemical Catalog Company, New York, 1928.

"Fundamentals of Dairy Science" is the first book published in the English language that deals with dairy science as a science. Its publication is a recognition of the importance of dairy science and it should assist in promoting a better understanding of and the need of research in certain phases of this branch of science.

This book was written by "Associates of Lore A. Rogers" in the research laboratories of the Bureau of Dairy Industry, United States Department of Agriculture and dedicated to him in recognition of his contributions to pure science and its applications to industry. It is a valuable contribution to dairy science and its applications.

The book is divided into four parts which deal with "The Constituents of Milk," "The Physical Chemistry of Milk and its Products," "The Microbiology of Milk and Milk Products," "The Nutritive Value of Milk and Milk Products. The Physiology of Milk Secretion." It is noteworthy that the authors did not include studies of the breeding of dairy cattle and only a limited amount of material on feeding is presented as a part of the physiology of milk secretion.

The 28 authors of the book have written parts of or entire chapters treating subject material that has been in their special field of work. They present the status of our knowledge as given in the literature, in new unpublished material, and as critically interpreted by them. The extensiveness of the survey of existing literature is evident from the fact that 1332 references are given, yet some investigations that one might expect to find in this book are absent. Of necessity, there is much difference in the technicality and clearness of presentation due primarily to the variety of material presented, but to some extent to the styles of the different authors. It should be stated that those who edited the book were successful in correlating the contributions to make a uniform book and one which is surprisingly free from errors for so extensive a publication.

A reviewer would be extremely presumptuous to critically comment upon the material presented in a book of this character. One cannot be able to do more than accept a contribution on milk fat by Geo. E. Holm, on pigments of milk by L. S. Palmer, on acid-base equilibria by

W. M. Clark, on sources of bacteria in milk by J. M. Sherman, etc.; not to mention any of the various subjects presented by the other 24 authors. One can judge the book to best advantage by first reading those chapters dealing with work in which he has been active to learn if the subject has been completely and accurately presented, and by reading the contributions in which he wishes to gain more information to learn if it gives the knowledge desired. Considered in this manner the book is especially pleasing, not only to obtain the results of leading scientific investigations on a given subject but to gain an accurate, concise view of the subject as a whole.

A. C. DAHLBERG.

Physik der Milchwirtschaft. (Physics of the Milk Industry.) OTTO RAHN AND PAUL F. SHARP. Paul Parey, Berlin. 1928. 227 pages, 48 illustrations.

As stated by the authors in the preface, this is the first attempt to assemble into book form the mass of data dealing with the physics of milk. In view of the nature of the material presented, however, it would probably be more accurate to term the treatise "The physico-chemical aspects of milk and its products."

The data have been arranged so as to serve the technical as well as the research workers, hence there is necessarily a duplication of some of the material. For example—Chapters I–IX inclusive deal directly with the physical properties and various phenomena concerned with milk, cream and butter in terms of viscosity, milk foam, creaming, butter formation, butter structure, and water content of butter. Chapters X–XV deal with the following products: whipped cream, lactose, ice cream, casein, cheese, condensed milks, and dry milk. It is evident that the material in these chapters must necessarily duplicate some of the material in the preceding ones.

Presentation of the entire material from the standpoint of the various products, or from the standpoint of the fundamental physical properties concerned, would have led to a clearer and more concise outline. This criticism is, however, of a minor nature and should in no way militate against the value of the mass of excellent data presented.

The treatment of most of the subjects is thorough, especially that of cream rising, and butter formation and structure, and the data are well illustrated with tables and graphs. The literature citations are numerous and well chosen.

The book is an excellent contribution to the literature of dairy science.

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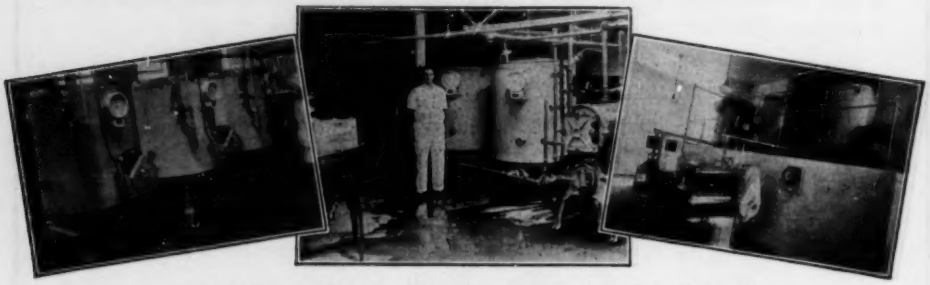

Among the many Pfaudler Pasteurizer advocates are: *Left*, Plymouth Dairy, Rochester, N. Y. *Center*, Glennie's Dairy, North Andover, Mass. *Right*, Spreckel's Creamery, Burlingame, Calif.

Through the science of bacteriology health ordinances are becoming more rigid. There is a new call to sanitation and the universality of pasteurization is, of course, the reflection of it. Lower bacterial counts and the insistence upon simplified dairy equipment represent the modern tendencies. Consequently a new interest has awakened in Pfaudler glass-lined equipment.

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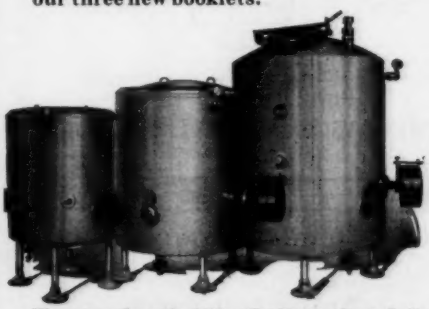

Three popular priced Pfaudler Pasteurizers: *Left*, the "C-Gal," 60-100-200 gallons; *Center*, the Open Pfaudlerette, 350 gallons; *Right*, the Closed Pfaudlerette, 350 gallons—all glass-lined, fully equipped and ready to operate.

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